Total Maximum Daily Load Development for Spring Branch

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CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

Background and Applicable Standards

Spring Branch was initially listed on the *1996 303(d) TMDL Priority List* as not supporting the aquatic life use (VADEQ, 1997). The cause(s) of the impairment at biological monitoring stations 5ASRN000.65, 5ASRN001.24 and 5ASRN003.69 were not known. Spring Branch was also listed as impaired on the *1998 303(d) Total Maximum Daily Load Priority List and Report* (VADEQ & VADCR, 1998) and the *2002 303(d) Report on Impaired Waters* (VADEQ, 2002) and the *2004 Virginia 305(b)/303(d) Water Quality Assessment Integrated Report* (VADEQ, 2004). Spring Branch carries an agency watershed ID of VAP-K32R. The Virginia Department of Environmental Quality (VADEQ) has identified Spring Branch as being impaired with regard to the General Standard (benthic). The impairment begins at the confluence with an unnamed tributary to Spring Branch that received the discharge from the former Borden Chemical facility downstream to the confluence of Spring Branch with the Blackwater River, a distance of 3.72 stream miles.

The General Standard is implemented by VADEQ through application of the modified Rapid Bioassessment Protocol II (RBPII). Using the modified RBPII, the health of the benthic macro-invertebrate community is typically assessed through measurement of eight biometrics that evaluate the overall health of the community. Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.,* non-impaired, slightly impaired, moderately impaired, or severely impaired). Using this methodology, Spring Branch was rated as severely impaired. The EPA has recently begun encouraging the use of multimetric indexes in determining benthic macroinvertebrate impairment. An index called the Coastal Plain Metric Index (CPMI) was developed specifically for use in low relief streams (USEPA, 1999). The CPMI confirms the findings of the modified RBPII method that the VADEQ benthic monitoring stations in Spring Branch are impaired.

Benthic Stressor Identification

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not, but generally do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (USEPA, 2000) was used to identify stressors affecting Spring Branch. Chemical and physical monitoring data from VADEQ monitoring stations provided evidence to support or eliminate potential stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity, temperature and organic matter.

The results of the stressor analysis for Spring Branch were divided into three categories:

> **Non-Stressor**: Those stressors with data indicating normal conditions, without water quality standard violations or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.
>
> **Possible Stressor**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.
>
> **Most Probable Stressor**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

The results indicate that total phosphorus is the Most Probable Stressor for Spring Branch because of its relationship to low dissolved oxygen and high pH. Total phosphorus was therefore used to develop the benthic TMDL.

Total phosphorus is delivered to Spring Branch through point source discharges, surface runoff, and natural processes. During runoff events, total phosphorus is transported to Spring Branch from land areas. Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of total phosphorus loading.

Total phosphorus transport is a natural and continual process that is often accelerated by human activity. A change in cropping practices can sometimes lead to more total phosphorus reaching the stream. New construction and logging can increase the amount of total phosphorus in the stream because it binds to sediment particles.

TMDL Endpoint

There is currently no water quality standard for total phosphorus in the state of Virginia. Bryant Pond has a long history of hyper-eutrophic conditions and this has resulted in pH values that exceed the maximum standard of 9.0 (std units) downstream of the pond. Therefore, it was logical to select the total phosphorus concentrations in the pond as the endpoint to eliminate the eutrophic conditions and the maximum pH standard violations. In addition, total phosphorus reductions upstream of the pond will lessen the severity of minimum dissolved oxygen concentration violations that occur between the Town of Waverly and the pond. Respiration by algal plant growth at night reduces the amount of dissolved oxygen available for other aquatic life. If this plant growth becomes excessive (due the availability of nutrients such as total phosphorus), dissolved oxygen concentrations can become too low to support some aquatic life. Therefore, reductions in total phosphorus will improve the benthic macroinvertebrate populations at VADEQ monitoring stations 5ASRN001.24 and 5ASRN000.65.

Carlson's Trophic State Index (TSI) is a measure of the trophic state of a waterbody and can be used to measure the water quality of a lake or pond. The TSI endpoint selected was 60, the threshold at which eutrophic conditions are triggered in lakes and reservoirs. A TSI of 60 corresponds to a total phosphorus concentration of 48.1 µg/L in Bryant Pond. Therefore, 48.1 µg /L total phosphorus was used as the TMDL endpoint in this study.

Water Quality Modeling

EUTROMOD, a model developed by Dr. Kenneth Reckhow at Duke University and later modified by Dr. W. Cully Hession at the Academy of Natural Sciences in Philadelphia, Pennsylvania, was selected as the modeling framework to model total phosphorus loads in Bryant Pond. The EUTROMOD model is a watershed-scale nutrient loading and lake response model. EUTROMOD utilizes the Rational Equation to estimate average annual runoff volumes, and the Universal Soil Loss Equation (USLE) to estimate annual erosion. EUTROMOD then estimates the associated dissolved phosphorus loads and sediment-bound phosphorus loads. Additionally, the model provides the option of including phosphorus loads from precipitation, septic systems, and other permitted and unpermitted discharges.

Existing Conditions

Both point and nonpoint sources of total phosphorus were represented in the model during the total phosphorus calibration period. Phosphorus inputs to the model include the point source loads from the Spring Branch Wastewater Treatment Facility, and uncontrolled discharges such as failing septic systems and sewer line leaks. Nonpoint sources of phosphorus are input to the model as sediment-attached phosphorus, and dissolved and total phosphorus in runoff.

Load Allocation Scenarios

The next step in the total phosphorus TMDL process was to adjust total phosphorus loadings from existing watershed conditions to reduce the various source loads to levels that would result in an in-stream total phosphorus concentration of less than 48.1 µg/L. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Allocations were developed at Bryant Pond in Spring Branch (Table ES.1).

Table ES.1 Land-based and direct nonpoint source load reductions in the Spring Branch impairment for final allocation.

Pollutant Source	Total Annual Loading for Existing Run (kg/yr)	Total Annual Loading for Allocation Run (kg/yr)	Percent Reduction
NonPoint Source			
Agriculture	251.32	41.97	83.3
Former Borden Chemical Site	0.89	0.15	83.3
Forest	5.67	5.67	0.0
Urban	0.56	0.09	83.3
Point Source			
Failing Septic Systems	66.46	0.00	100.0
Sewer Line Leak	36.62	0.00	100.0
Permitted Discharge*	872.40	145.82	83.3

*annual loading based on permitted discharge of 0.90MGD and a concentration less than 0.12 mg/L TP for the allocated condition.

The TMDL established for this stream consists of a permitted point source wastewater allocation (WLA), a nonpoint source load (LA) and a margin of safety (MOS). The TMDL equation is as follows:

TMDL = WLA +LA + MOS

The WLA portion of this equation is the total loading assigned to permitted point sources. The LA portion represents the loading assigned to non-point sources. The MOS is the portion of the loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis.

The nutrient loads from all of the nonpoint and point sources were added together to determine the total annual total phosphorus load to Spring Branch. A total phosphorus TMDL was then developed for the impaired segment based on the results from the load allocation scenarios (Table ES.2).

Table ES.2 Annual TP loads (kg/yr) modeled after TMDL allocation in the Spring Branch impairment.

Impairment	WLA (kg/year)	LA (kg/year)	MOS	TMDL (kg/year)
Spring Branch	145.82	47.88	*Implicit*	193.70

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop a TMDL that will result in meeting water quality standards. This report represents the culmination of that effort for the total phosphorus impairment in Spring Branch. The second step is the development of TMDL implementation plans. The final step is to implement the TMDL implementation plan, and to monitor water quality to determine if water quality standards are being attained.

Once the United States Environmental Protection Agency (EPA) approves a TMDL, measures must be taken to reduce pollution levels in the stream. These measures, which can include the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource.

To address the total phosphorus TMDL, it is anticipated that the VPDES discharge will be required to discharge a reduced concentration of total phosphorus. Additionally, in both urban and rural areas, reducing the phosphorus loading from failing septic systems and sewer line leaks should be a primary implementation focus because of the health implications. In agricultural areas of the watershed, promising management practices include improved nutrient management, use of cover crops, and runoff management systems such as grass swales and buffers. These practices have been shown to be effective in lowering phosphorus concentrations in streams.

There is a measure of uncertainty associated with the final allocation development process. Monitoring performed upon completion of specific implementation milestones can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the 303(d) list.

Public Participation

During development of the TMDL for Spring Branch, public involvement was encouraged through two public meetings in the watershed. In addition, two separate technical advisory meetings were held. An introduction of the agencies involved, an overview of the TMDL process, and the specific approach to developing the Spring Branch TMDL were presented at the first of the public meetings. Details of the pollutant sources and stressor identification were also presented at this meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The final model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting and five written comments were received and addressed. Watershed stakeholders will have the opportunity to participate in the development of the TMDL implementation plan (IP).

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1. INTRODUCTION

1.1 Background

The United States Environmental Protection Agency's (EPA) document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (USEPA, 1999) states:

> *According to Section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs .*
>
> *. . . A TMDL, or total maximum daily load, is a tool for implementing State water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

Spring Branch was initially listed on Virginia's *1996 303(d) TMDL Priority List* as not supporting the aquatic life use. It was also listed on the *1998 303(d) Total Maximum Daily Load Priority List and Report*, the *2002 303(d) Report on Impaired Waters*, and the *2004 305(b)/303(d) Water Quality Assessment Integrated Report*. Spring Branch carries an agency watershed ID of VAP-K32R. The Virginia Department of Environmental Quality (VADEQ) has identified Spring Branch as being impaired with regard to the General Standard (benthic).

The Spring Branch watershed (within USGS Hydrologic Unit Code #03010202) is located in Virginia's Sussex County (Figure 1.1). The impaired stream segment extends from the most upstream discharge at the former Borden Chemical Waverly Plant downstream to the mouth of Spring Branch at its confluence with the Blackwater River, a length of 3.72 miles. Spring Branch flows into the Blackwater River, which is part of the Chowan River Basin that drains to the Currituck Sound. The land area of the Spring Branch watershed is approximately 3,746 acres. Land use in the Spring Branch watershed is primarily forest (67%) and agriculture (27%), with the remaining area divided among urban areas and water bodies.

Initially, there were four biological monitoring stations on Spring Branch: 5ASRN003.82, 5ASRN003.69, 5ASRN001.24, and 5ASRN000.65. All of the stations, with the exception of 5ASRN003.82, were rated severely impaired for the 1996 and 1998 305(b) assessment cycles. All of the stations, with the exception of 5ASRN003.82, were rated moderately to severely impaired for the 2002 305(b) assessment cycle. VADEQ added another benthic monitoring station in 2004, 5ASRN001.99. Based upon the three benthic surveys in 2004 and 2005, Spring Branch is also impaired at this monitoring site. The VADEQ reports that the source of the impairment is unknown.

There is one municipal discharge. The two industrial discharges in the watershed have been terminated since the 1998 303(d) list was compiled. There are also extensive sludge deposits, attributed to the old Waverly primary sewage treatment plant (1930s – 1976) in Spring Branch and Bryant Pond, 0.25 mile downstream of the Spring Branch Wastewater Treatment Facility discharge.

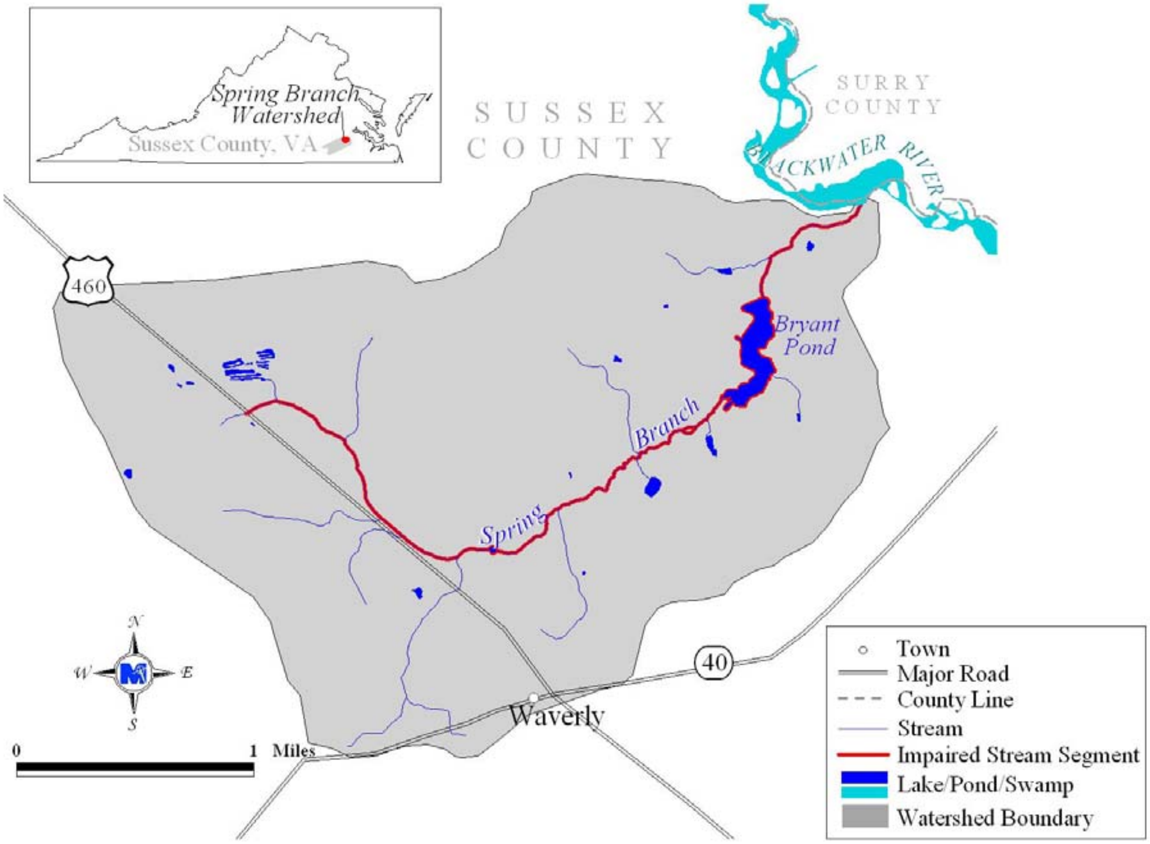

Figure 1.1 The Spring Branch watershed and its impaired segment.

2. WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

Virginia state law 9VAC25-260-10 (Designation of uses) indicates:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of <u>a balanced, indigenous population of aquatic life</u>, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

♦

D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.

♦

G. The [State Water Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:

1. *Naturally occurring pollutant concentrations prevent the attainment of the use;*
2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*

♦

6. *Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

2.2 Applicable Criterion for Benthic Impairment

Additionally, Virginia state law 9VAC25-260-20 defines the **<u>General Standard</u>** as:

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or <u>aquatic life</u>.

2.3 Benthic Assessment – Spring Branch

All biological and ambient water quality monitoring stations on Spring Branch are shown in Table 2.1 and Figure 2.1. While some chlorophyll and nutrient data was collected from Bryant Pond beginning in 2004 (5ASRN000.66), this data is not considered representative of Spring Branch as a flowing stream.

Table 2.1 Benthic and ambient monitoring stations in the Spring Branch watershed.

Station	Station Type[1]	Description	River Mile
5ASRN000.65	Ambient/Bio	Below Bryant Pond	0.65
5ASRN001.24	Ambient/Bio	Below Spring Branch WTF	1.24
5ASRN001.99	Ambient/Bio	Spring Branch Rd, Rt. 653	1.99
5ASRN003.69[2]	Ambient/Bio	East side of Rt. 460 Bridge, below trib. from former Borden Chemical site	3.69
5ASRN003.82[3]	Ambient/Bio	Upstream of trib. draining the former Borden Chemical site	3.82
5AXFG000.04	Ambient	Trib. draining the former Borden Chemical site	0.04
5AXAW000.19	Ambient	Trib. draining former Masonite site	0.19
5ASRN000.66	Special Study	Bryant Pond	0.66

[1] Bio: Biological; Ambient: Ambient water quality.
[2] Station name was recently corrected from 5ASRN002.66.
[3] Station name was recently corrected from 5ASRN002.69.

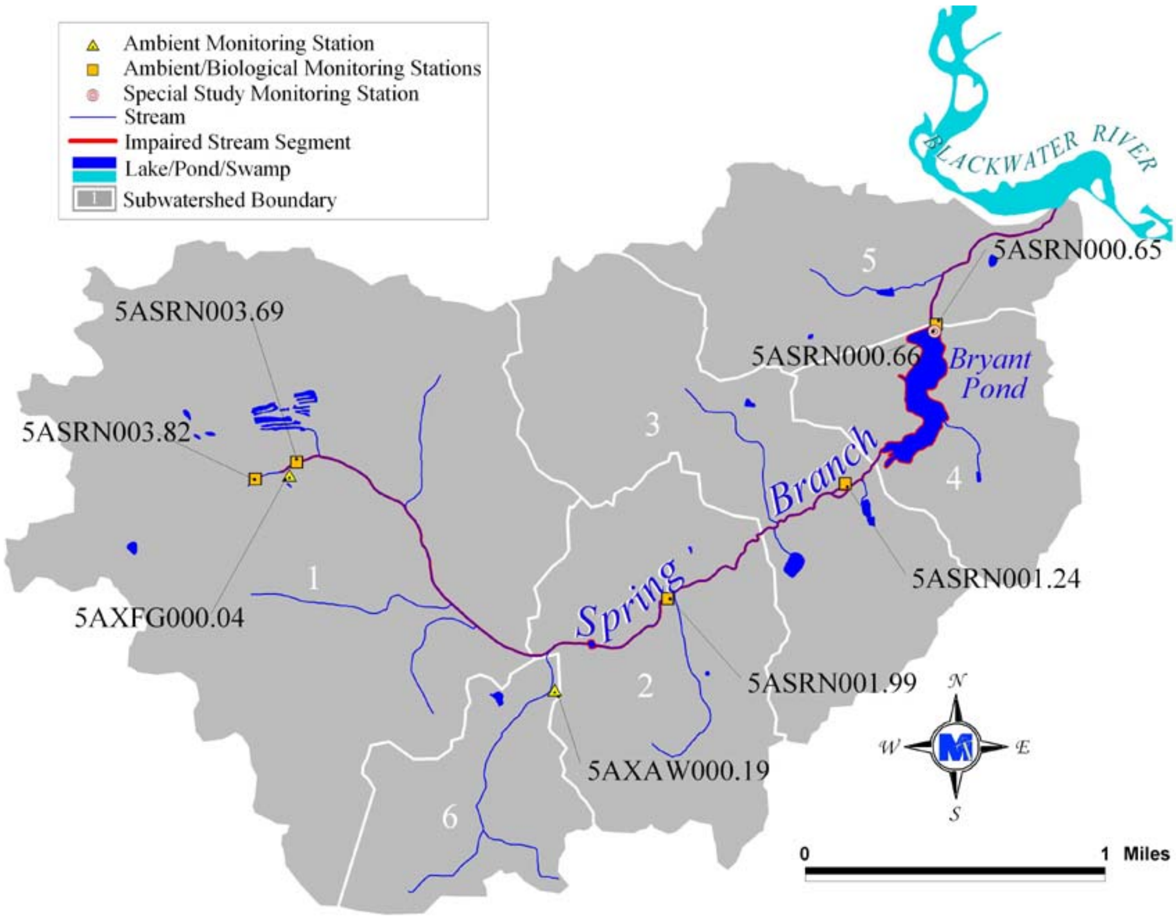

Figure 2.1 Biological and ambient water quality monitoring stations on Spring Branch.

Modified Rapid Bioassessment Protocol II (RBP II) benthic surveys were performed by VADEQ from the spring of 1992 through the spring of 1998 and resumed again in the spring of 2004. The surveys were conducted throughout Spring Branch (Figure 2.1). Modified RBP II scores could not be accurately calculated from the 48 surveys conducted between 1994 and 1998 because there was no data to calculate many of the metrics. The most upstream station on Spring Branch, 5ASRN003.82, was used as the reference station because a suitable reference station on another stream could not be found, and it bracketed a known pollution source (the former Borden Chemical plant VPDES permitted discharge). The reported results were based on the professional experience of the VADEQ biologist because modified RBP II scores could not be calculated due to the intermittent nature of the reference station (Tables 2.2 and 2.3). The Coastal Plain Metric

Index (CPMI), discussed later in this chapter, confirms the results reported by the VADEQ biologist for these surveys.

Table 2.2 Modified RBP II biological monitoring results for Spring Branch (spring 1992 - fall 1994).

STATION	S_92	F_92	S_93	F_93	S_94	F_94
5ASRN000.65	MI	SI	SI	SI	SI	SI
5ASRN001.24	SI	SI	SI	SI	SI	SI
5ASRN003.69	SI	SI	SI	SI	SI	SI
5ASRN003.82	REF	REF	REF	NA	REF	REF

NI = "Not Impaired", MI = "Moderately Impaired", SI = "Severely Impaired", NA = Not Assessed, REF = "Reference Station"

Table 2.3 Modified RBP II biological monitoring results for Spring Branch (spring 1995 – spring 1998).

STATION	S_95	S_96	F_96	S_97	F_97	S_98
5ASRN000.65	MI	NI	SLI	NI	SLI	MI
5ASRN001.24	SI	SI	SI	SI	SI	MI
5ASRN003.69	SI	MI	MI	MI	MI	MI
5ASRN003.82	REF	REF	REF	REF	REF	REF

NI = "Not Impaired", SLI = "Slightly Impaired", MI = "Moderately Impaired", SI = "Severely Impaired"

The biological monitoring conducted in 2004 and 2005 contained sufficient organisms to accurately calculate modified RBP II scores at most of the monitoring stations; the results are presented in Tables 2.4 through 2.6. For these surveys, the reference station was on Warwick Swamp (5AWKS001.00), which was the most appropriate of the available reference streams. Tables 2.2 and 2.3 indicate that moderately to severely impaired conditions were periodically found at stations 5ASRN000.65, 5ASRN001.24 and 5ASRN003.69. Both 2004 surveys and the spring 2005 survey show considerable improvement at these three monitoring stations.

Table 2.4 Modified RBP II biological monitoring data for Spring Branch (spring 2004).

RPB II Metric	5AWKS001.00 5/13/2004		5ASRN000.65 5/13/2004		5ASRN001.24 5/13/2004		5ASRN001.99 5/11/2004		5ASRN003.69 5/11/2004		5ASRN003.82 5/11/2004	
	Value	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**
Taxa Richness	14	6	9	4	10	4	17	6	10	4	2	2
MFBI	6.13	6	6.75	6	6.79	6	5.81	6	6.28	6	6	6
SC/CF	0.69	6	0.6	6	NA	NA	2.67	6	0.18	2	0	6
EPT/Chi Abund	0.19	6	0.01	0	0.12	4	1.46	6	0.64	6	2	0
% Dominant	55.34	0	72.04	0	46.67	0	35.85	2	43.75	0	0	0
EPT Index	2	6	1	0	1	0	1	0	1	0	6	0
Comm. Loss Index	0	6	0.89	4	0.8	4	0.41	6	1	4	4	4
SH/Tot	0.01	6	NA	NA	0.00	NA	0.01	0	0.02	NA		NA
Biological Condition Score		**36**		**20**		**18**		**32**		**22**		**18**
% of Reference		**100**		**55.56**		**50.0**		**88.89**		**61.11**		**50.00**
		Reference		**Slight**		**Moderate**		**No Impact***		**Slight**		**Moderate**

* No Impact = Not Impaired

Table 2.5 Modified RBP II biological monitoring data for Spring Branch (fall 2004).

RPB II Metric	5AWKS001.00 11/5/2004		5ASRN000.65 11/3/2004		5ASRN001.24 11/32004		5ASRN001.99 11/3/2004		5ASRN003.69 11/5/2004		5ASRN003.82 11/5/2004	
	Value	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**
Taxa Richness	16	6	12	4	14	6	13	6	9	2	11	4
MFBI	5.25	6	6.29	4	6.24	4	5.34	6	6.25	4	6.64	4
SC/CF	2.3	6	2.38	6	0.06	0	0.75	2	0.30	0	0.11	0
EPT/Chi Abund	0.83	6	1.33	6	1.09	6	1.87	6	0.52	4	0.14	0
% Dominant	38.18	2	26.67	4	33.33	2	49.11	0	40.78	0	56.86	0
EPT Index	5	6	3	0	5	6	2	0	2	0	2	0
Comm. Loss Index	0	6	0.83	4	0.57	4	0.69	4	1.11	4	0.91	4
SH/Tot		NA		NA		NA		NA		NA		NA
Biological Condition Score		**38**		**28**		**28**		**24**		**14**		**12**
% of Reference		**100**		**73.68**		**73.68**		**63.16**		**36.84**		**31.58**
		Reference		**Slight**		**Slight**		**Slight**		**Moderate**		**Moderate**

Table 2.6 Modified RBP II biological monitoring data for Spring Branch (spring 2005).

RPB II Metric	5AWKS001.00 5/3/2005		5ASRN000.65 5/3/2005		5ASRN001.24 5/3/2005		5ASRN001.99 5/5/2005		5ASRN003.69 5/3/2005	
	Value	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**	**Metric**	**Score**
Taxa Richness	13	6	17	6	8	4	15	6	12	6
MFBI	6.19	6	6.37	6	7.41	4	6.1	6	6.5	6
SC/CF	2.00	6	1.38	6	1.2	6	0.67	2	0.6	2
EPT/Chi Abund	0.16	6	2.33	6	0.35	6	0.21	6	0.06	2
% Dominant	60.78	0	29.00	4	50.96	0	63.87	0	69.79	0
EPT Index	6	6	3.00	0	2.00	0	1.00	0	2.00	0
Comm. Loss Index	0.00	6	0.41	6	1.13	4	0.53	4	0.75	4
SH/Tot		NA		NA						NA
Biological Condition Score		**36**		**34**		**24**		**24**		**20**
% of Reference		**100**		**94.44**		**66.67**		**66.67**		**55.56**
		Reference		**No Impact***		**Slight**		**Slight**		**Slight**

*No Impact = Not Impaired

EPA recently approved a Virginia Stream Condition Index (VASCI) for non-tidal portions of Virginia for testing to see if further calibration is necessary before it replaces the modified RBP II procedure. The advantage of the VASCI is that the score does not depend on values from a reference station. Its use is still questionable in watersheds east of the Blue Ridge Mountains in Virginia. However, a similar index has been developed for use in low relief areas of eastern Virginia. This index is called the Coastal Plain Metric Index (CPMI), which has an impairment threshold of 24 (USEPA, 1999). The CPMI scores for the VADEQ surveys on Spring Branch are presented in Tables 2.7 through 2.11 and Figure 2.2. Table 2.12 shows the CPMI scores for Warwick Swamp, the reference station for Spring Branch.

Table 2.7 CPMI scores for station 5ASRN000.65.

	Date														
Metric	**5/18/92**	**11/25/92**	**5/21/93**	**11/3/93**	**5/13/94**	**11/16/94**	**5/4/95**	**4/18/96**	**11/15/96**	**5/15/97**	**11/20/97**	**5/11/98**	**5/13/04**	**11/3/04**	**5/3/05**
TotTaxa Score	2	0	0	0	0	0	2	2	2	2	2	2	2	4	6
HBI Score	2	0	0	6	0	0	4	0	2	0	2	0	2	4	2
EPTTax Score	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
%Ephem Score	2	0	0	0	0	0	0	0	0	0	0	0	0	6	4
%ClngP Score	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
CPMI Score	**6**	**0**	**4**	**6**	**0**	**0**	**6**	**2**	**4**	**2**	**4**	**2**	**4**	**16**	**16**

Table 2.8 CPMI scores for station 5ASRN001.24.

	Date														
Metric	**5/18/92**	**11/25/92**	**5/21/93**	**11/3/93**	**5/13/94**	**11/16/94**	**5/4/95**	**4/18/96**	**11/15/96**	**5/15/97**	**11/20/97**	**5/11/98**	**5/13/04**	**11/3/04**	**5/3/05**
TotTaxaScore	0	0	0	0	0	0	0	0	0	0	0	0	2	4	2
HBIScore	0	0	4	0	0	0	2	0	0	0	0	2	2	4	0
EPTTaxScore	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2
%EphemScore	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
%ClngPScore	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
CPMIScore	**0**	**0**	**4**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**2**	**4**	**20**	**4**

Table 2.9 CPMI scores for station 5ASRN001.99.

	Date		
Metric	**5/11/04**	**11/3/04**	**5/5/05**
TotTaxaScore	4	4	4
HBIScore	4	6	2
EPTTaxScore	0	0	0
%EphemScore	6	6	2
%ClngPScore	0	0	0
CPMIScore	**14**	**16**	**8**

Table 2.10 CPMI scores for station 5ASRN003.69.

	Date														
Metric	**11/16/94**	**5/4/95**	**4/18/96**	**11/15/96**	**5/15/97**	**11/16/94**	**5/4/95**	**4/18/96**	**11/15/96**	**5/15/97**	**11/19/97**	**5/11/98**	**5/11/04**	**11/5/04**	**5/5/05**
TotTaxaScore	0	2	2	0	2	0	2	2	0	2	2	2	2	2	4
HBIScore	6	4	2	4	0	6	4	2	4	0	0	2	4	4	2
EPTTaxScore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
%EphemScore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
%ClngPScore	0	0	0	0	0	0	0	0	0	0	0	0	6	4	0
CPMIScore	**6**	**6**	**4**	**4**	**2**	**6**	**6**	**4**	**4**	**2**	**2**	**4**	**12**	**10**	**8**

Table 2.11 CPMI scores for station 5ASRN003.82.

	Date												
Metric	**5/18/92**	**11/25/92**	**5/21/93**	**5/13/94**	**11/16/94**	**5/4/95**	**4/18/96**	**11/15/96**	**5/15/97**	**11/19/97**	**5/11/98**	**5/11/04**	**11/5/04**
TotTaxaScore	2	0	2	0	2	2	2	0	2	2	2	2	2
HBIScore	4	6	4	0	2	4	2	6	0	2	2	4	2
EPTTaxScore	0	0	0	0	0	0	0	0	0	0	0	0	0
%EphemScore	0	0	0	0	0	0	0	0	0	0	0	0	0
%ClngPScore	0	0	0	0	0	0	0	0	0	0	0	0	0
CPMIScore	**6**	**6**	**6**	**0**	**4**	**6**	**4**	**6**	**2**	**4**	**4**	**6**	**4**

Table 2.12 CPMI scores for reference station 5AWKS001.00*.

Metric	Date 5/13/04	11/5/04	5/3/05
TotTaxaScore	6	4	4
HBIScore	4	6	2
EPTTaxScore	4	4	6
%EphemScore	0	4	0
%ClngPScore	2	4	0
CPMIScore	**16**	**22**	**12**

*Warwick Swamp reference station.

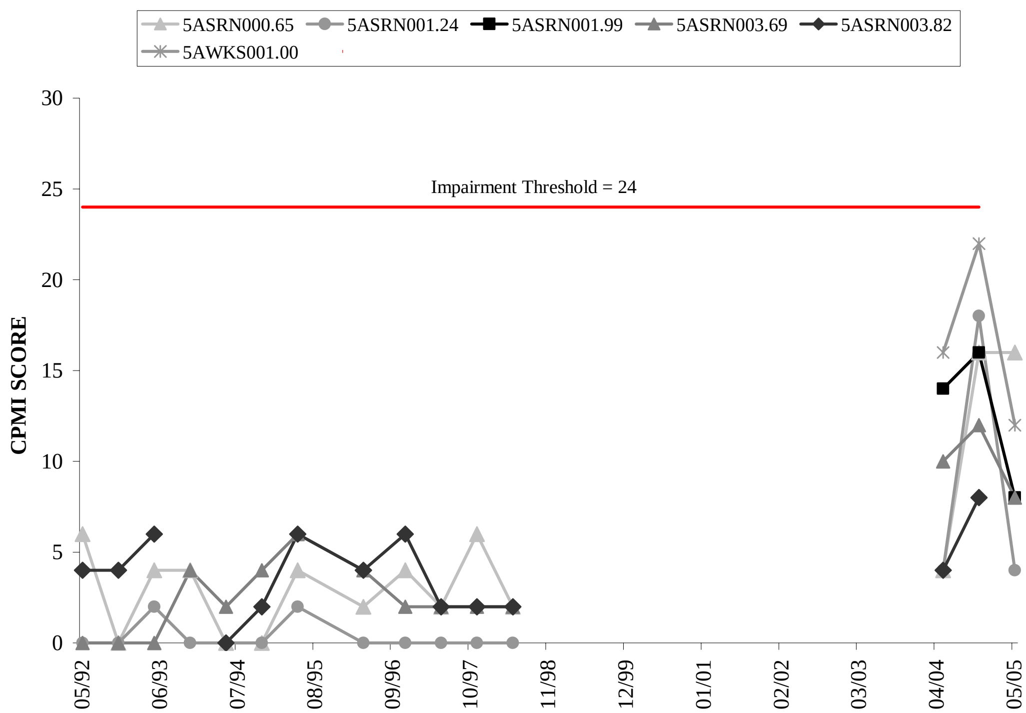

Figure 2.2 CPMI scores for VADEQ benthic surveys on Spring Branch, 1994 – 1998, 2004, and 2005.

2.4 Habitat Assessments

Benthic impairments have two general causes: input of pollutants to streams, and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.*, by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.*, due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of ten individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 2.13.

Table 2.13 Classification of habitat metrics based on score.

HABITAT METRIC	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
Embeddedness	16 – 20	11 – 15	6 - 10	0 – 5
Pool Substrate	16 – 20	11 – 15	6 - 10	0 – 5
Epifaunal Substrate	16 – 20	11 – 15	6 - 10	0 – 5
Pool Sediment	16 – 20	11 – 15	6 - 10	0 – 5
Flow	16 – 20	11 – 15	6 - 10	0 – 5
Channel Alteration	16 – 20	11 – 15	6 - 10	0 – 5
Riffles	16 – 20	11 – 15	6 - 10	0 – 5
Channel Sinuosity	16 – 20	11 – 15	6 - 10	0 – 5
Velocity	16 – 20	11 – 15	6 - 10	0 – 5
Pool Variability	16 – 20	11 – 15	6 - 10	0 – 5
Bank Stability	18 – 20	12 – 16	6 - 10	0 – 4
Bank Vegetation	18 – 20	12 – 16	6 - 10	0 – 4
Riparian Vegetation	18 – 20	12 – 16	6 - 10	0 – 4

2.4.1 Habitat Assessment at Biological Monitoring Stations on Spring Branch

Habitat assessment for Spring Branch includes an analysis of habitat scores recorded by the VADEQ biologists from 1994 to 1998; these results are displayed in Table 2.14. (Scores for the spring 1992 – spring 1994 surveys are not available.) Scores for embeddedness, riparian vegetation, and sediment were low for every station except 5ASRN001.24. Changes were made to the modified RBP II protocols for habitat assessments made after 2000. Because some of the metrics were more appropriate for high gradient streams composed of pool/riffle areas, the changes involved adding metrics more appropriate for assessing low gradient streams. Therefore, in this study, more weight was given to the habitat assessments done in 2004 and 2005. Low scores for embeddedness and sediment indicate that significant amounts of habitat are not available for benthic marcroinvertebrates. Riparian vegetation provides a buffer from pollutants that may enter the stream in runoff and it also prevents erosion. Epifaunal substrate scores were low at every monitoring station. This parameter indicates the quality and quantity of natural structures in the stream such as fallen trees, logs, branches and undercut banks, which are habitat sites for aquatic macrofauna. Finally, scores for riffles and velocity were low at most of the monitoring stations; however, these parameters are most suited to high gradient streams and Spring Branch is a low gradient stream.

Table 2.14 Median habitat scores for VADEQ monitoring stations fall 1994 – spring 1998.

HABITAT METRIC	5ASRN000.65	5ASRN001.24	5ASRN003.69	5ASRN003.82
Channel Alteration	4	20	20	19
Bank Stability	6	12	18	14
Bank Vegetation	10	14	14	16
Embeddedness	7	12	0	6
Flow	20	20	18	20
Riffles	9	6	6	4
Riparian Vegetation	10	18	10	8
Sediment	10	11	8	0
Epifaunal Substrate	4	6	0	1
Velocity	12	4	6	2
TOTAL	**92**	**123**	**100**	**90**

The Spring 2004, Fall 2004 and Spring 2005 habitat results for the four impaired benthic monitoring stations on Spring Branch were good overall. The two downstream monitoring stations (5ASRN001.24 and 5ASRN000.65) had marginal scores for pool substrate and channel sinuosity. Marginal pool substrate scores indicate that the stream bottom is mostly mud or clay and there is little or no root mat or submerged vegetation. Low scores for channel sinuosity indicated a stream channel that is almost straight. The most upstream monitoring station (5ASRN003.69) had marginal scores for pool substrate and pool variability. Marginal pool variability scores indicate that the stream at the monitoring site has a lot of shallow pools rather than a mixture of deep and shallow ones. Habitat assessment scores for the surveys conducted during 2004 and 2005 are shown in Table 2.15.

Table 2.15 Habitat scores for VADEQ monitoring stations during 2004 and 2005.

HABITAT METRIC	5ASRN000.65		5ASRN001.24		5ASRN001.99		5ASRN003.69		5ASRN003.82	
	5/13/04	11/3/04	5/13/04	11/3/04	5/11/04	11/3/04	5/11/04	11/5/04	5/11/04	11/5/04
Channel Alteration	16	18	18	15	19	18	18	18	14	13
Bank Stability	18	18	18	20	18	20	16	18	16	18
Bank Vegetation	16	17	17	18	14	18	12	18	14	18
Flow	16	17	16	17	17	17	9	18	9	19
Pool Substrate	9	10	9	9	11	12	9	10	11	11
Pool Variability	13	15	12	14	13	17	8	10	9	8
Riparian Vegetation	19	19	19	18	20	19	19	19	17	17
Sediment	14	16	16	16	13	17	14	16	18	17
Channel Sinuosity	6	9	6	7	14	14	14	13	8	7
Epifaunal Substrate	14	11	14	12	12	14	11	11	9	9
TOTAL	**141**	**150**	**145**	**146**	**151**	**166**	**130**	**151**	**125**	**137**

Table 2.15 Habitat scores for VADEQ monitoring stations during 2004 and 2005 (cont.)

HABITAT METRIC	5ASRN000.65	5ASRN001.24	5ASRN001.99	5ASRN003.69
	5/03/05	5/03/05	05/05/05	05/05/05
Channel Alteration	17	17	19	19
Bank Stability	20	20	20	18
Bank Vegetation	18	16	16	16
Flow	18	14	15	13
Pool Substrate	10	11	13	9
Pool Variability	9	12	13	9
Riparian Vegetation	19	19	19	17
Sediment	12	14	16	15
Channel Sinuosity	11	10	12	12
Epifaunal Substrate	12	11	16	11
TOTAL	**146**	**144**	**159**	**139**

2.5 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream monitoring data throughout Spring Branch. Data from water quality stations used in Section 305(b) assessment and data collected during TMDL development were analyzed and discussed.

2.5.1 Inventory of Water Quality Monitoring Data

The primary source of available water quality information for Spring Branch is data collected at five sites by the VADEQ (Table 2.16).

Table 2.16 VADEQ monitoring stations in the Spring Branch watershed.

Station	Stream Name	Data Record
5ASRN000.65	Spring Branch	7/2003 – 3/2005
5ASRN001.24	Spring Branch	7/2003 – 3/2005
5ASRN001.99	Spring Branch	7/2003 – 3/2005
5ASRN003.69*	Spring Branch	3/1990 – 6/1990, 7/2003 – 3/2005
5ASRN003.82	Spring Branch	10/2003 – 3/2005
5AXFG000.04	Spring Branch X-Trib (former Borden Chemical Site)	7/2003 – 3/2005
5AXAW000.19	Spring Branch X-Trib (Masonite Site)	2/2005 – 3/2005
5ASRN000.66	Bryant Pond	5/2004 – 3/2005

*Data collected prior to 1990 is considered historic data.

2.5.2 VADEQ Water Quality Monitoring – Spring Branch watershed

Only stations with at least nine data points were used in the stressor identification evaluation (Chapter 3) unless extreme values were reported. This was done for statistical accuracy and to ensure that data used for the stressor identification represented every season. The data for the five monitoring stations is summarized in Tables 2.17 through 2.21. Note the low dissolved oxygen and high pH values. The data for Bryant Pond and the two unnamed tributaries to Spring Branch are summarized in Tables 2.22 through 2.24.

Table 2.17 In-stream Water Quality Data for 5ASRN000.65.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	4.6	3.5	18.0	2.0	4.0	16
DO_Probe (mg/L)	9.5	9.2	18.0	5.0	3.1	21
Field_pH (std units)	7.5	7.3	9.1	6.6	0.8	21
Total ammonia (mg/L)	0.41	0.10	4.00	0.04	1.08	13
Nitrite + Nitrate (mg/L)	0.7	0.6	1.2	0.0	0.4	10
Orthophosphate (mg/L)	0.15	0.12	0.29	0.06	0.08	21
Total phosphorus (mg/L)	0.3	0.2	2.1	0.1	0.4	20
Temperature (Celsius)	16.8	14.7	30.3	4.5	7.9	21
Total Kjeldahl Nitrogen (mg/L)	1.9	0.9	12.5	0.5	2.8	19
Conductivity (μmhos/cm)	234	241	380	120	72	21
NO2-N (mg/L)	0.03	0.01	0.07	0.01	0.03	7
NO3-N (mg/L)	0.9	0.5	2.6	0.0	0.9	9
Settleable solids (ml/L)	0.6	0.6	1.0	0.1	0.6	2
Total suspended solids (mg/L)	14.3	7.5	67.0	3.0	18.9	18
NH3 MUD DRY WGT MG/KG-N	5.2	NA	5.2	5.2	NA	1
ORGAN. NMUD D WTMG/KG-N	410	NA	410	410	NA	1
PHOS MUD DRY WGTMG/KG-P	270	NA	270	270	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.18 In-stream Water Quality Data for 5ASRN001.24.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	2.9	3.0	5.0	2.0	1.0	16
DO_Probe (mg/L)	8.0	8.0	12.5	2.9	2.4	21
Field_pH (std units)	7.0	6.9	8.7	6.4	0.6	21
Total ammonia (mg/L)	0.23	0.11	1.41	0.04	0.36	14
Nitrite + Nitrate (mg/L)	0.87	0.93	3.12	0.04	0.88	11
Orthophosphate (mg/L)	0.53	0.41	1.58	0.06	0.49	21
Total phosphorus (mg/L)	0.7	0.4	2.4	0.1	0.6	21
Temperature (Celsius)	16.7	15.5	27.4	5.2	6.5	21
Total Kjeldahl Nitrogen (mg/L)	1.5	1.0	10.2	0.5	2.1	20
Conductivity (μmhos/cm)	266	217	605	105	130	21
NO2-N (mg/L)	0.04	0.02	0.16	0.01	0.05	9
NO3-N (mg/L)	1.7	1.8	3.0	0.4	1.0	10
Settleable solids (ml/L)	0.4	0.5	0.5	0.2	0.2	3
Total suspended solids (mg/L)	9.2	5.5	33.0	3.0	7.3	20
NH3 MUD DRY WGT MG/KG-N	38	NA	38	38	NA	1
ORGAN. NMUD D WTMG/KG-N	1,100	NA	1,100	1,100	NA	1
PHOS MUD DRY WGTMG/KG-P	490	NA	490	490	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.19 In-stream Water Quality Data for 5ASRN001.99.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	2.9	2.0	6.0	2.0	1.4	12
DO_Probe (mg/L)	6.4	6.9	12.5	0.8	3.7	21
Field_pH (std units)	6.5	6.5	7.0	5.8	0.3	21
Total ammonia (mg/L)	0.10	0.08	0.21	0.04	0.05	20
Nitrite + Nitrate (mg/L)	0.25	0.21	0.75	0.06	0.21	11
Orthophosphate (mg/L)	0.03	0.02	0.05	0.02	0.01	16
Total phosphorus (mg/L)	0.1	0.1	0.1	0.0	0.0	15
Temperature (Celsius)	14.7	12.8	25.2	3.7	7.1	21
Total Kjeldahl Nitrogen (mg/L)	0.7	0.7	1.2	0.4	0.2	19
Conductivity (μmhos/cm)	116	105	223	51	43	21
NO2-N (mg/L)	0.01	0.01	0.01	0.01	0.00	4
NO3-N (mg/L)	0.2	0.2	0.3	0.1	0.1	10
Settleable solids (ml/L)	0.40	0.40	0.50	0.30	0.14	2
Total suspended solids (mg/L)	9.9	7.0	48.0	3.0	9.8	20
NH3 MUD DRY WGT MG/KG-N	24	NA	24	24	NA	1
ORGAN. NMUD D WTMG/KG-N	1,200	NA	1,200	1,200	NA	1
PHOS MUD DRY WGTMG/KG-P	170	NA	170	170	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.20 In-stream Water Quality Data for 5ASRN003.69.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	3.3	3.0	7.0	2.0	1.6	15
DO_Probe (mg/L)	6.5	6.9	11.8	0.7	3.0	21
Field_pH (std units)	6.2	6.2	6.7	5.6	0.3	21
Total ammonia (mg/L)	0.23	0.10	1.16	0.04	0.30	16
Nitrite + Nitrate (mg/L)	0.19	0.14	0.47	0.05	0.15	7
Orthophosphate (mg/L)	0.05	0.04	0.11	0.02	0.04	5
Total phosphorus (mg/L)	0.09	0.05	0.40	0.02	0.11	12
Temperature (Celsius)	14.3	12.6	24.4	1.3	7.0	21
Total Kjeldahl Nitrogen (mg/L)	1.2	0.9	4.7	0.4	1.0	19
Conductivity (μmhos/cm)	74	66	157	40	28	21
NO2-N (mg/L)	0.03	0.03	0.06	0.01	0.03	3
NO3-N (mg/L)	0.5	0.1	2.0	0.1	0.8	6
Settleable solids (ml/L)	0.30	0.20	0.50	0.20	0.17	3
Total suspended solids (mg/L)	33.1	11.5	214.0	3.0	53.0	20
NH3 MUD DRY WGT MG/KG-N	130	NA	130	130	NA	1
ORGAN. NMUD D WTMG/KG-N	590	NA	590	590	NA	1
PHOS MUD DRY WGTMG/KG-P		NA	66	66	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.21 In-stream Water Quality Data for 5ASRN003.82.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	3.8	3.5	7.0	2.0	1.7	8
DO_Probe (mg/L)	6.1	6.1	9.8	2.7	2.5	13
Field_pH (std units)	6.1	6.3	6.5	5.5	0.3	13
Total ammonia (mg/L)	0.09	0.07	0.19	0.05	0.06	5
Nitrite + Nitrate (mg/L)	0.31	0.31	0.57	0.04	0.37	2
Total phosphorus (mg/L)	0.05	0.04	0.14	0.02	0.04	8
Temperature (Celsius)	15.1	14.3	24.1	5.7	6.8	13
Total Kjeldahl Nitrogen (mg/L)	0.8	0.6	2.0	0.4	0.5	10
Conductivity (μmhos/cm)	69	63	114	47	21	13
NO2-N (mg/L)	0.01	NA	0.01	0.01	NA	1
NO3-N (mg/L)	0.11	0.11	0.12	0.11	0.01	2
Settleable solids (ml/L)	0.68	0.30	2.00	0.10	0.90	4
Total suspended solids (mg/L)	35.2	11.5	280.0	3.0	77.5	12
NH3 MUD DRY WGT MG/KG-N	23	NA	23	23	NA	1
ORGAN. NMUD D WTMG/KG-N	1,400	NA	1,400	1,400	NA	1
PHOS MUD DRY WGTMG/KG-P	120	NA	120	120	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.22 In-stream Water Quality Data for 5ASRN000.66.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	36.1	19.0	128.0	2.0	43.6	8
DO_Probe (mg/L)	9.8	8.2	18.0	0.7	5.2	10
Field_pH (std units)	7.6	7.2	9.5	6.6	1.0	10
Total ammonia (mg/L)	1.60	0.65	3.80	0.35	1.91	3
Nitrite + Nitrate (mg/L)	0.16	0.11	0.48	0.05	0.13	9
Total phosphorus (mg/L)	1.50	0.51	4.88	0.17	1.80	7
Temperature (Celsius)	19.0	20.2	31.6	7.5	8.7	10
Total Kjeldahl Nitrogen (mg/L)	6.2	3.8	17.2	0.9	6.4	6
Conductivity (μmhos/cm)	228	242	294	137	58	10
NO2-N (mg/L)	0.04	0.05	0.07	0.01	0.03	4
NO3-N (mg/L)	0.93	0.60	2.60	0.04	1.01	8
Settleable solids (ml/L)	0.58	0.60	1.00	0.10	0.49	4
Total suspended solids (mg/L)	64.9	63.0	142.0	11.0	50.5	8

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.23 In-stream Water Quality Data for 5AXFG000.04.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	11.64	8.00	59.00	2.00	14.79	14
DO_Probe (mg/L)	5.94	5.97	10.14	1.51	2.64	15
Field_pH (std units)	6.57	6.65	7.12	5.51	0.43	15
NH3+NH4-N TOTAL MG/L	1.24	0.65	6.10	0.15	1.59	14
Nitrite + Nitrate (mg/L)	17.39	18.20	27.90	2.14	10.00	5
PHOS-T ORTHO MG/L P	0.05	0.04	0.08	0.03	0.02	8
Total phosphorus (mg/L)	0.14	0.10	0.80	0.03	0.20	14
Temperature (Celsius)	15.14	12.34	26.54	3.74	7.95	15
Total Kjeldahl Nitrogen (mg/L)	5.50	5.13	12.00	2.60	2.64	14
Conductivity (μmhos/cm)	254	262	393	98	93	15
NO2-N (mg/L)	0.14	0.11	0.36	0.02	0.14	8
NO3-N (mg/L)	10.47	9.76	22.72	1.21	8.74	8
T ALK CACO3 MG/L	27.60	NA	27.60	27.60	NA	1
Settleable Solids (ml/L)	1.68	0.10	8.00	0.10	3.53	5
Total suspended solids (mg/L)	635.37	30.00	3,781.00	11.00	1,198.83	15
TURBIDTY LAB NTU	37.00	NA	37.00	37.00	NA	1
NH3 MUD DRY WGT MG/KG-N	26.00	NA	26.00	26.00	NA	1
ORGAN. NMUD D WTMG/KG-N	1,500.00	NA	1,500.00	1,500.00	NA	1
PHOS MUD DRY WGTMG/KG-P	150.00	NA	150.00	150.00	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.24 In-stream Water Quality Data for 5AXAW000.19.

Parameter	Mean	Median	Max	Min	SD[1]	N[2]
BOD_5 (mg/L)	3.00	NA	3.00	3.00	NA	1
DO_Probe (mg/L)	10.36	10.36	10.51	10.21	0.21	2
Field_pH (std units)	6.16	6.155	6.44	5.87	0.40	2
NH3+NH4-N TOTAL MG/L	0.97	0.965	1.40	0.53	0.62	2
PHOS-T ORTHO MG/L P	0.04	0.035	0.04	0.03	0.01	2
Total phosphorus (mg/L)	0.11	0.105	0.17	0.04	0.09	2
RESIDUE TOT NFLT MG/L	33.50	33.5	59.00	8.00	36.06	2
Temperature (Celsius)	7.84	7.84	10.03	5.65	3.10	2
Total Kjeldahl Nitrogen (mg/L)	1.75	1.75	2.00	1.50	0.35	2
NO2-N (mg/L)	0.01	0.01	0.01	0.01	0.00	2
NO3-N (mg/L)	0.94	0.94	1.09	0.79	0.21	2
Specific_Conductance	139	139	150	128	16	2

[1]SD: standard deviation, [2]N: number of sample measurements

2.5.3 Special Studies and Water Quality Problems

Historically, concerns with low dissolved oxygen (DO) and high ammonia concentrations prompted the State Water Control Board (SWCB) and the VADEQ Piedmont Regional Office (PRO) to conduct special intensive studies of Spring Branch and its tributaries in 1972 and 1993. The PRO office of the VADEQ sampled 12 sites on Spring Branch and its tributaries from February 1993 through August 1993. They found that DO concentrations generally declined from upstream to downstream and, beginning as early as May, many values were below the minimum water quality standard of 4.0 mg/L. The primary reasons for the low DO concentrations in the upper portion of Spring Branch are the natural swamp conditions and numerous beaver dams. In addition, just upstream of the Rt. 653 Bridge (river mile 1.99) an old milldam had been breached, which resulted in a loss of riparian shade for a large wetland area. A very thick blanket of filamentous green algae covered the area following this event. The largest decline in DO concentrations occurred on August 11, 1993 from the Rt. 653 bridge (4.2 mg/L) to the last monitoring station 200 feet downstream from the Town of Waverly Sewage Treatment Plant (STP) discharge (1.46 mg/L). The VADEQ believed that one of the reasons for the sharp decline in DO in that area was the presence of seven more beaver dams that slow down the velocity of the stream, causing organic matter to build up behind them. Decomposition of the organic matter can lower the DO and pH of the surrounding water. Another possible reason for the low DO concentrations is due to a legacy pollution problem. From the 1930s until 1976, a primary STP provided treatment for the wastewater generated by the Town of Waverly. The discharge was located on a tributary that drains to Spring Branch just below the Rt. 653 bridge. The plant was permitted to release significant quantities of solids and organic matter into the receiving stream. Upon entering Spring Branch, these solids were captured by beaver dams downstream. The accumulation of solids in Spring Branch became so severe that the SWCB performed a special study in October 1972. They found that the sludge deposits from the STP were severely impacting Spring Branch from the tributary's confluence to Bryant Pond, 1.32 miles downstream. The VADEQ speculated in 1993 that these historic solids deposits, termed "oxidizable benthic deposits", could have been partially responsible for the rapid decline in DO concentrations in the vicinity of the Town of Waverly. It should also be noted that Bryant Pond, located at river mile 0.66 or approximately 1.6 miles downstream from the Town of Waverly, has suffered from a severe algal problem for at least 35 years. Monitoring station 5ASRN000.65 is located just downstream of the overflow from the pond, and the large masses of dead and dying algae contribute to a significant organic matter buildup at this monitoring station. In addition, the fluctuations in pH and DO due to photosynthetic activity as well as organic decomposition negatively impact Spring Branch at this monitoring station. It is likely that there is a nutrient cycling process occurring in the pond that will continue to cause excessive algal growth and associated eutrophication in the future. This problem is aggravated by excessive inputs of nutrients from the Town of Waverly and the Spring Branch Wastewater Treatment Facility discharge. The VADEQ believes that the excessive algal growth on Bryant Pond originally occurred because of the organic pollution from the primary STP serving the Town of Waverly.

Another pollution source was a glue-manufacturing site most recently owned by Borden Chemical (formerly operated under the names Wright Chemical and Spurlock) located near the headwaters of Spring Branch just off Rt. 460. The process of making glue requires mixing formaldehyde with urea resin. Urea is a nitrogenous compound that breaks down in the presence of water into ammonia, which is toxic to aquatic life. However, toxicity testing of the effluent from Borden Chemical in the early 1990s showed no evidence of toxicity. In addition, the discharge monitoring report (DMR) data indicated no significant problems with ammonia in the discharge. In the presence of water, formaldehyde breaks down into formalin; an intermediate product is formic acid. A review of historic monitoring data (January 1980 through June 1990) from VADEQ monitoring station 5ASRN003.69 shows periodic spikes in nitrogen parameters and total suspended solids. This monitoring station is located just downstream from the tributary that received the discharge from the former Borden Chemical plant. During a 1971 special study by the SWCB on the impact of Wright Chemical (which has subsequently been owned and operated by Spurlock, and then by Borden Chemical) on Spring Branch, no living benthic organisms were found at 5ASRN003.69 and the stream bottom was covered with a yellow residue from the discharge. Production ceased at the Borden Chemical plant in January 2001 and VADEQ began monitoring the unnamed tributary (5AXFG000.04) below the former Borden Chemical plant site in 2003. Even though the plant has not been in operation for four years, it appears that waste products are periodically reaching the tributary to Spring Branch. Ultimately, this has the potential to impact Spring Branch. Anecdotal information asserts that significant quantities of unused material were buried on-site. Table 2.25 shows the results of a few selected parameters collected on January 14, 2004.

Table 2.25 Selected parameters sampled at 5AXFG000.04 on January 14, 2004.

Parameter	Value
Total ammonia (mg/L)	1.58
NO_2_NO_3-N (mg/L)	27.90
NO_3-N (mg/L)	22.72
Total Kjeldahl nitrogen (mg/L)	10.10
BOD_5 (mg/L)	59
Total suspended solids (mg/L)	3,781
Dissolved oxygen (mg/L)	4.78

A comparison was done between the “current” (7/2003 – 12/2004) ambient monitoring data for station 5ASRN003.69 and a “historic” time period (1/1980 – 6/1990) when the Spurlock plant was in operation. Table 2.26 shows the general statistics for appropriate parameters collected during the historic time period. An example of a box-and-whisker plot is shown in Figure 2.3 and a comparison of historic and current data using box-and-whisker plots is provided in Figures 2.4 through 2.12. In several cases, the actual maximum value was not used in the graph because it was so extreme the detail in the plots would not have been visible. Another suitable value from the dataset was used for the maximum value in those graphs.

Table 2.26 General statistics for constituents sampled at 5ASRN003.69 (January 1980 – June 1990).

Parameter	Median	Maximum	Minimum	Count
Total ammonia (mg/L)	0.40	140	0.07	104
Total Kjeldahl nitrogen (mg/L)	1.0	490	0.20	108
Nitrate nitrogen (mg/L)	0.14	28	0.04	75
BOD_5 (mg/L)	2.0	380	1.0	111
Total suspended solids (mg/L)	7.0	228	1.0	67
Dissolved oxygen (mg/L)	8.2	11.2	3.6	107
pH (std units)	8.0	9.3	6.1	110
Temperature (Celsius)	22.0	39	7.0	111
Conductivity (µmhos/cm)	318.0	1,682	56.8	114

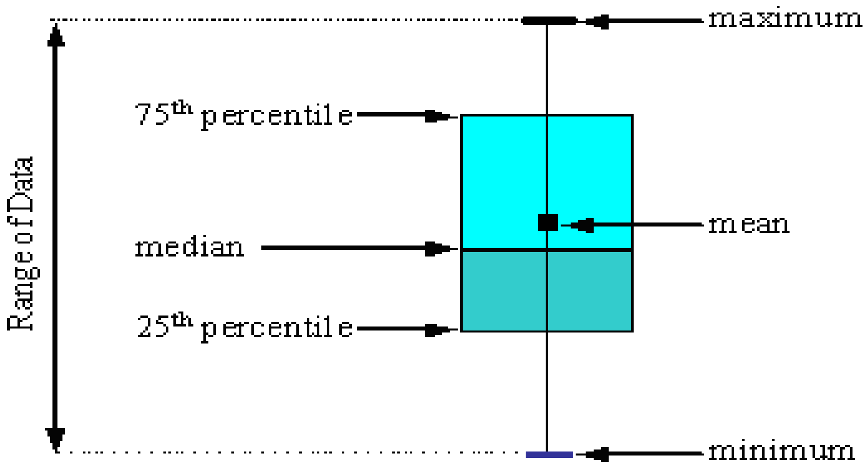

Figure 2.3 Box-and-whisker plot explanation.

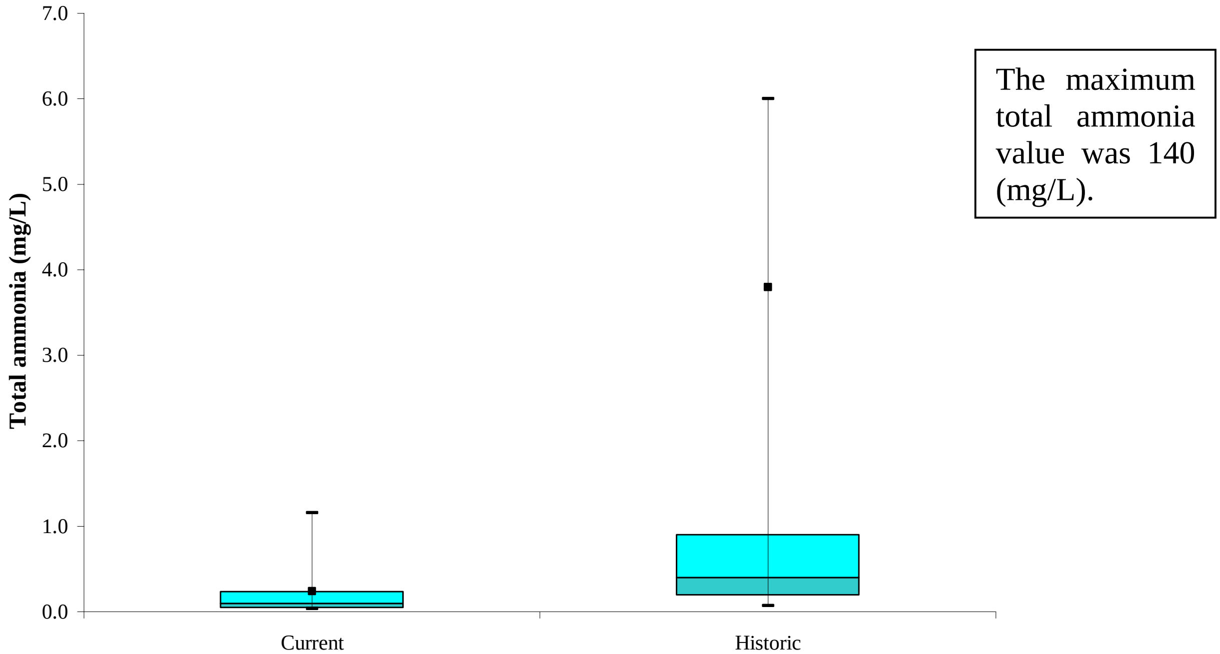

Figure 2.4 NH_3/NH4 – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

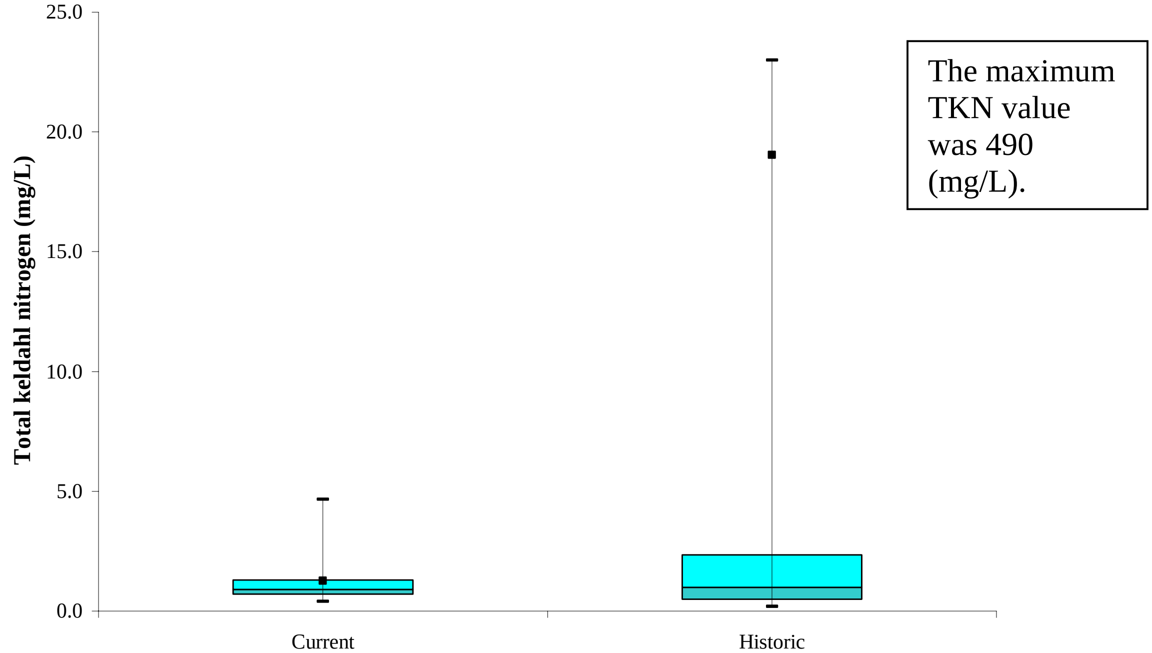

Figure 2.5 TKN – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

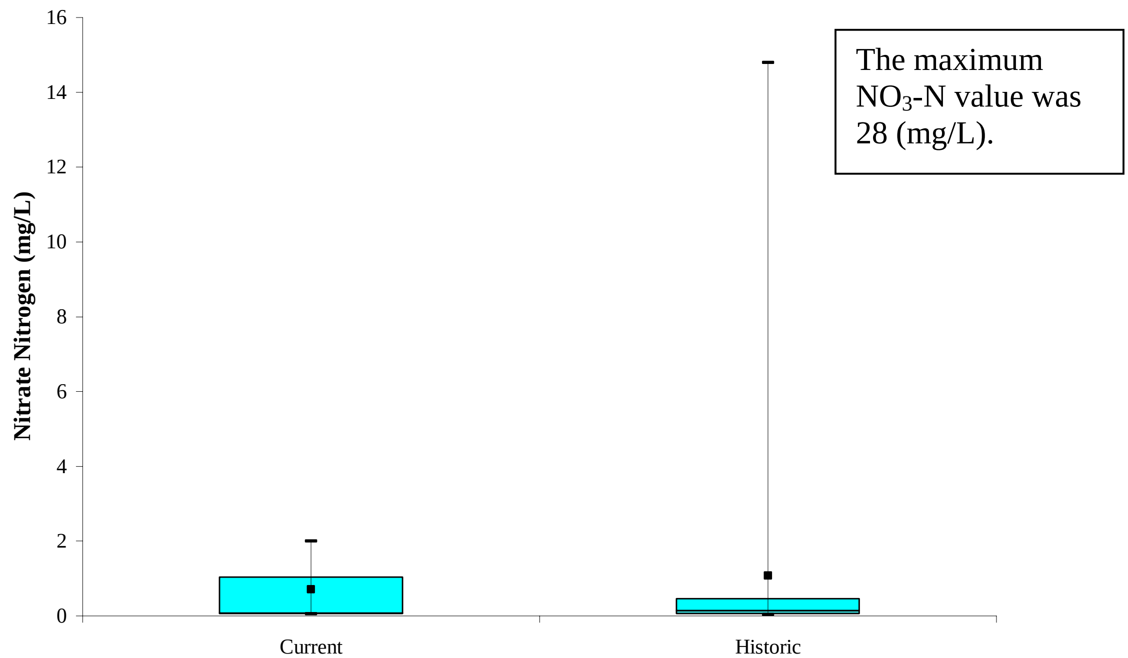

Figure 2.6 NO_3-N – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

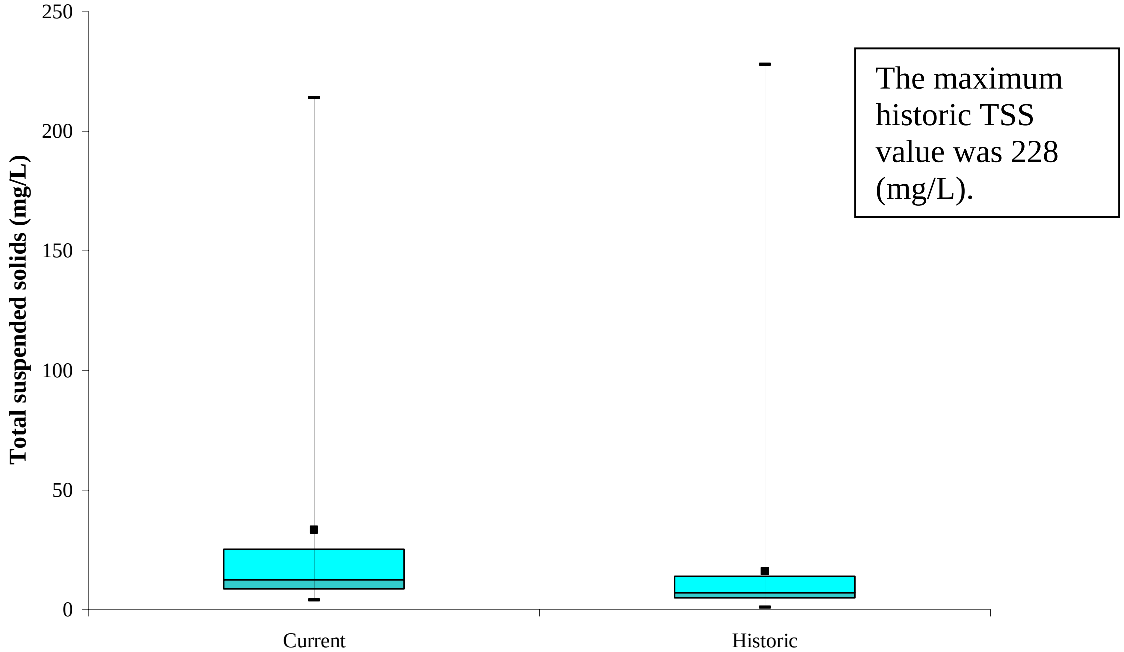

Figure 2.7 TSS – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

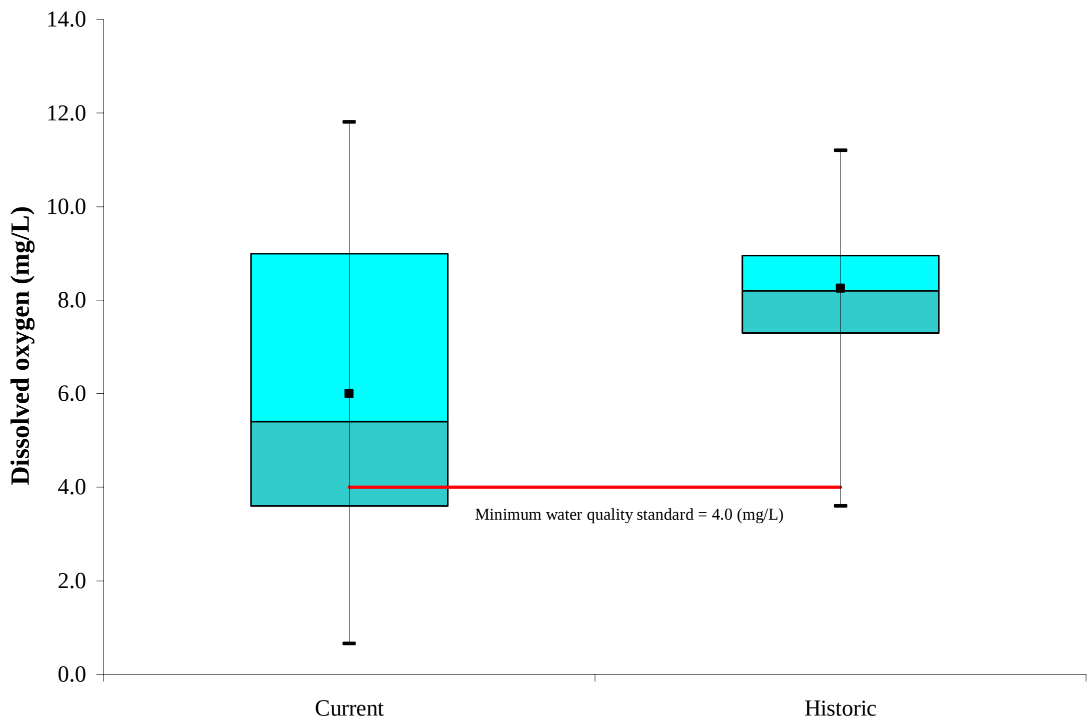

Figure 2.8 DO – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

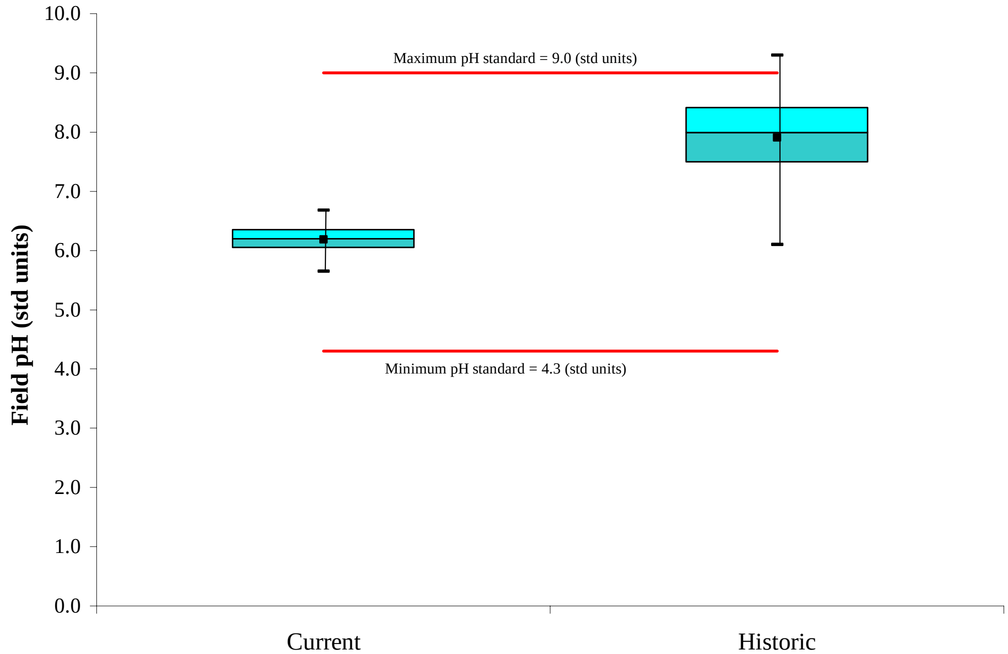

Figure 2.9 Field pH – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

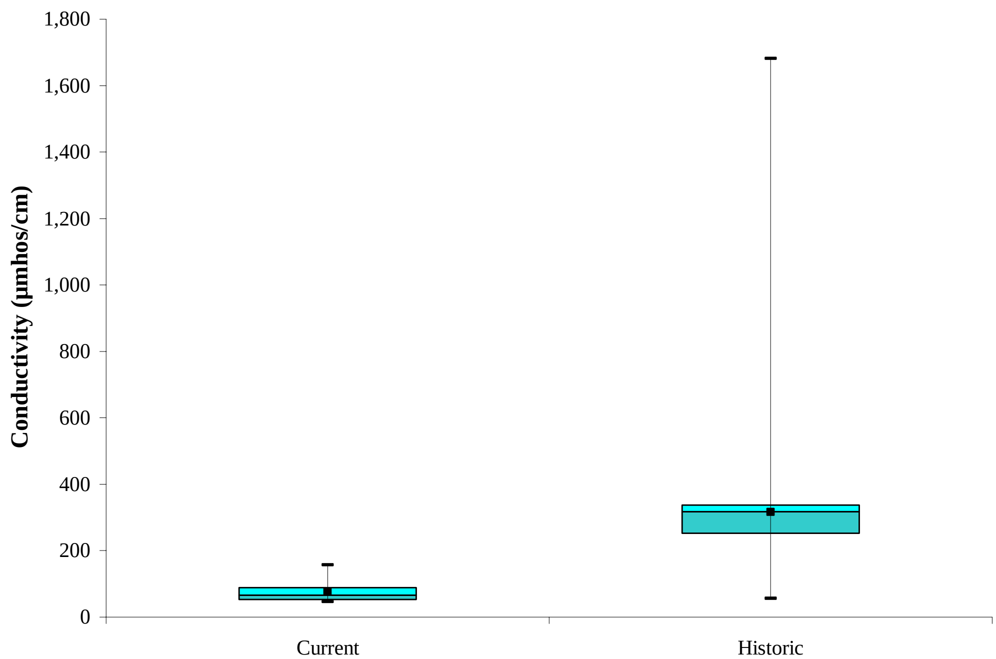

Figure 2.10 Conductivity – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

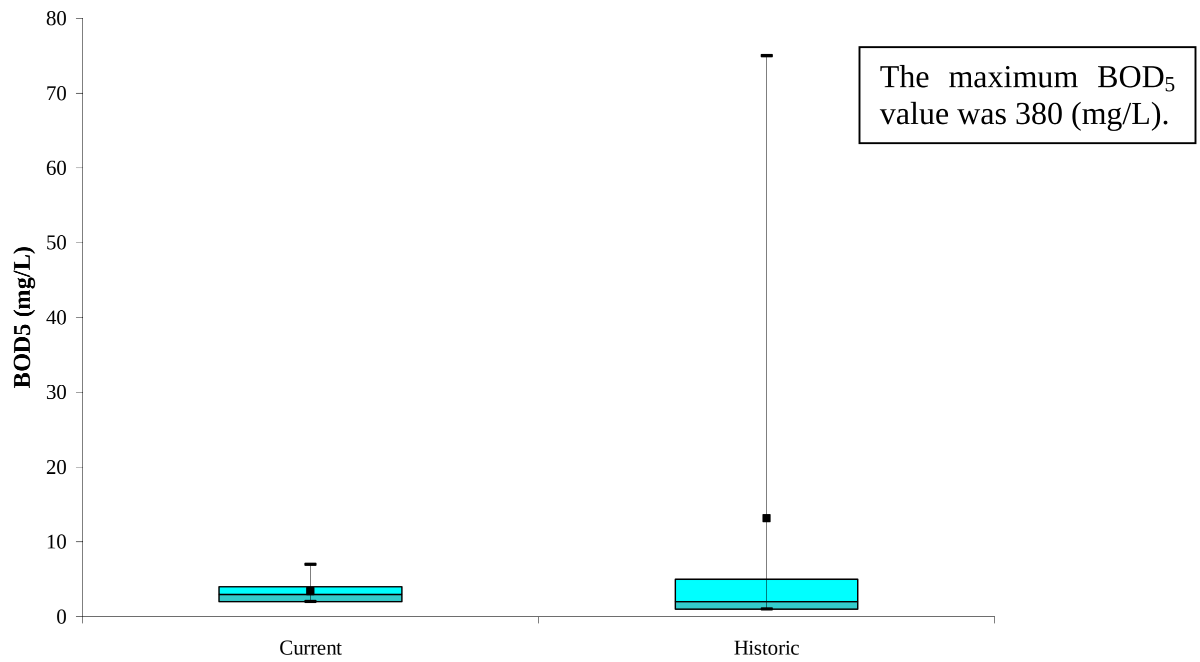

Figure 2.11 BOD_5 – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

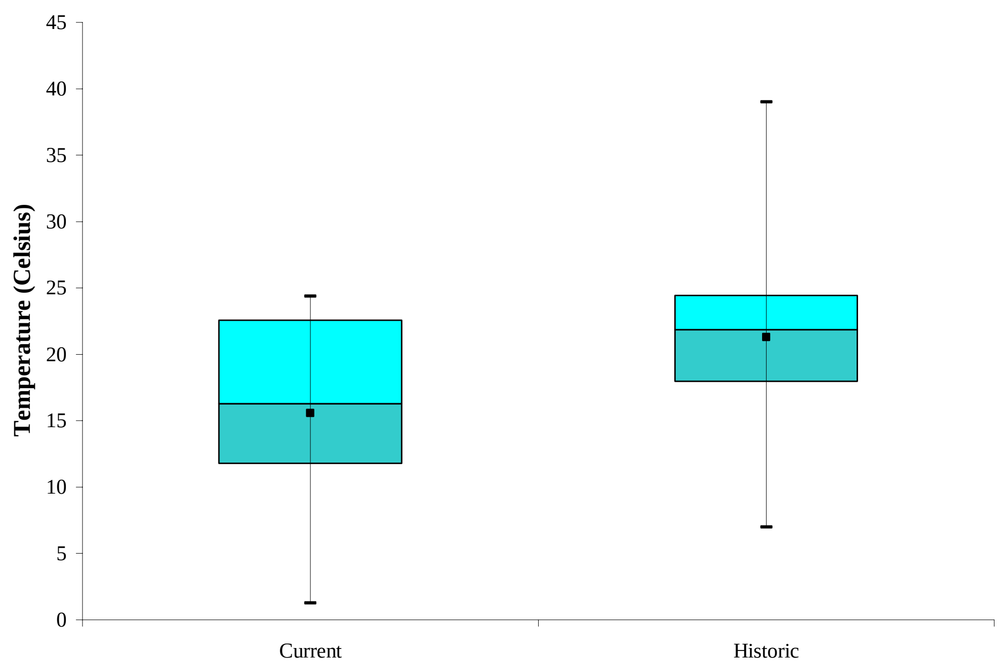

Figure 2.12 Temperature – current (7/2003 – 12/2004) and historic (1/1980 – 6/1990) at monitoring station 5ASRN003.69.

Figure 2.13 is a plot of the ratio of total ammonia concentrations against the chronic ammonia water quality standard. The red line represents the standard at a ratio of 1.0. Twenty six percent of the total ammonia concentrations between January 1980 and June 1990 exceeded the ammonia chronic water quality standard. Figure 2.14 is a plot of the ratio of total ammonia concentrations against the acute ammonia water quality standard. The red line represents the standard at a ratio of 1.0. In the early 1980s, nine total ammonia concentrations exceeded the acute standard. Both figures show much lower concentrations when VADEQ resumed sampling at monitoring station 5ASRN003.69 in July 2003 after Borden Chemical closed.

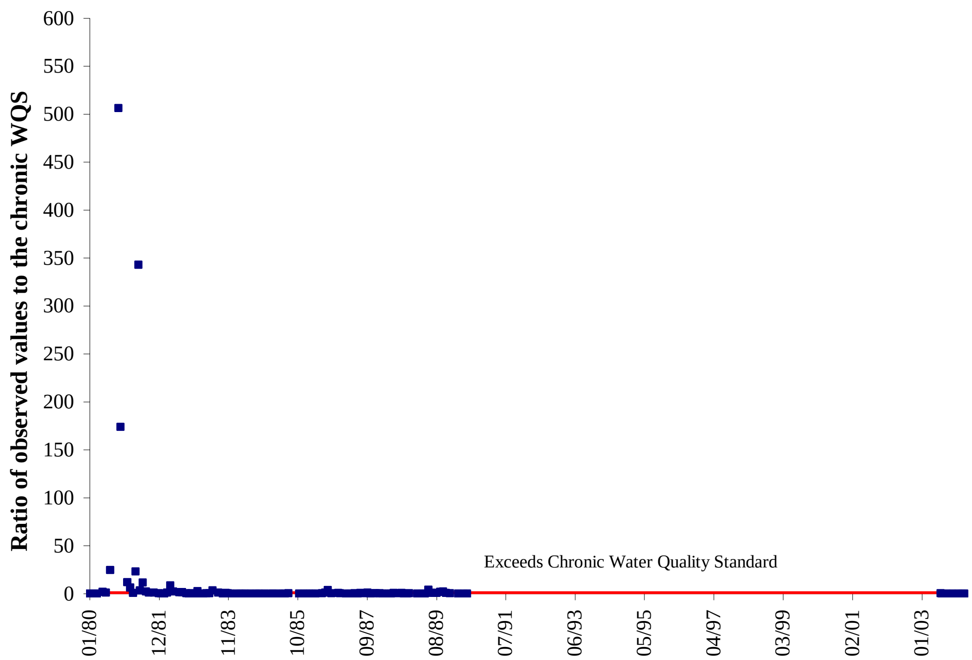

Figure 2.13 Ratio of observed total ammonia concentrations to the chronic water quality standard at 5ASRN003.69.

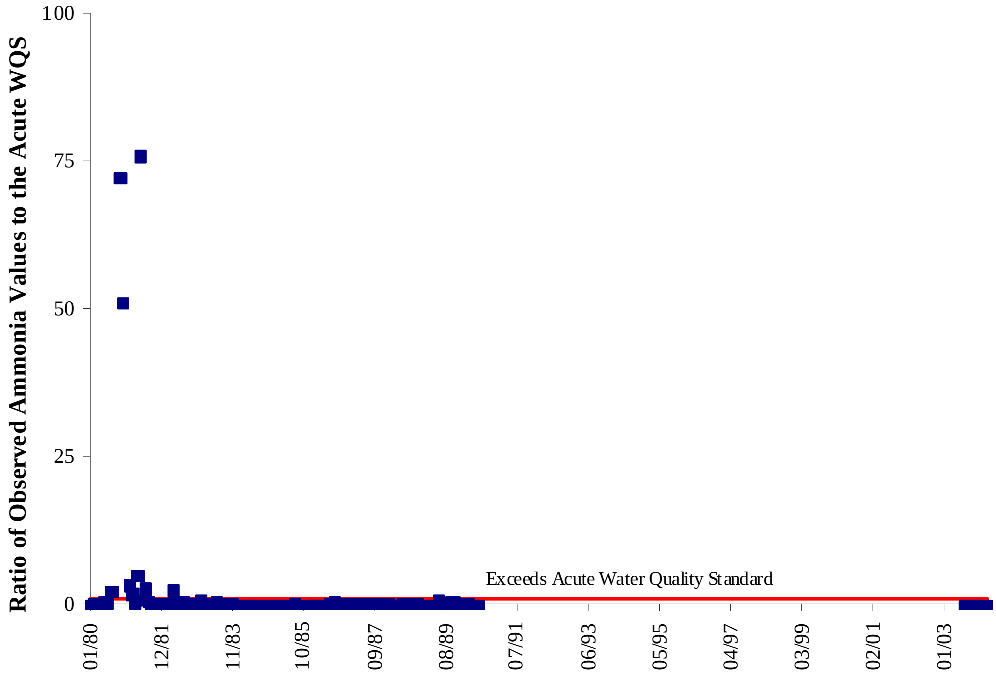

Figure 2.14 Ratio of observed total ammonia concentrations to the acute water quality standard at 5ASRN003.69.

Figures 2.13 and 2.14 clearly depict an improved condition over time with respect to ammonia, which is toxic to aquatic life. Section 2.1 documented the improvement in the benthic population at biological monitoring station 5ASRN003.69 after the closure of the Borden Chemical plant. Historical and recent total suspended solids concentrations are about the same and may be due to erosion at the old plant site. The former Borden Chemical site is now owned by Emanuel Tire Company. This site is an active tire chipping and recycling operation. There doesn't appear to be any active land disturbance on site.

During efforts to close the wastewater treatment facility at Borden Chemical, VADEQ required a limited subsurface investigation of the old lagoon area. In October 2002, groundwater samples were collected from four monitoring wells and sampled for formaldehyde, nitrogen species, and four volatile organic compounds. An ammonia-nitrogen concentration of 45 mg/L was measured in monitoring well number 2 (MW2). Follow up sampling was done on June 17, 2003. Groundwater samples were collected from four monitoring wells and soil samples taken at six different locations on the abandoned plant site in June 2003. An ammonia-nitrogen concentration of 76 mg/L was measured in MW2. The

Virginia Ground Water Standard (VAGS) for ammonia-nitrogen is 0.025 mg/L. In addition, nitrite/nitrate nitrogen concentrations of 140 and 48 mg/L were measured at MW2 and MW3, respectively. The VAGS standards for nitrite and nitrate-nitrogen are 0.025 and 5 mg/L, respectively. Chloroform concentrations in MW3 are below the mean concentration level (MCL) and above the chloroform risk-based concentration level (RBC). All soil parameters were found to be below RBC and dilution attenuation factor (DAF) concentrations, but formaldehyde concentrations were high in several soil samples. In the June 2003 sample at MW2, carbon disulfide was detected, but the concentration had to be estimated. It is not clear if the contamination came from the lagoon or if other processes were responsible. It has been confirmed that MW2 is located in the vicinity of the old septic drainfield that served the plant site. These results are consistent with stream water quality data collected on Spring Branch and the unnamed tributary that indicate periodic high concentrations of various nitrogen compounds.

VADEQ collected samples for chronic and acute toxicity testing from four ambient/biological monitoring sites on Spring Branch and a sample was also taken from Bryant Pond in November 2004. The results indicated acute and chronic toxicity to fathead minnows at stations 5ASRN003.69 and 5ASRN001.99. The EPA laboratory noted that conductivity values at the 5ASRN003.69 were below 100 and this can lead to an inaccurate result. Results from monitoring station 5ASRN001.24, located just downstream of the Spring Branch Wastewater Treatment Facility discharge, showed no toxicity. The results for the remaining two monitoring stations, 5ASRN000.65 and Bryant Pond (5ASRN000.66), indicated acute toxicity to fathead minnows only. A possible explanation for the toxicity in Bryant Pond and 5ASRN000.65 is toxins produced by competing algae. VADEQ requested that EPA conduct an additional review of the data. The USEPA Wheeling, West Virginia laboratory noted that the results of the toxicity testing should be carefully compared to existing water quality data.

On August 31, 2004 and February 28, 2005, VADEQ sampled for numerous organic compounds in an unnamed tributary to Spring Branch (5AXFG000.04) that once received the discharge from the former Borden Chemical plant site. The majority of the results were below laboratory detection levels. This data can be found in Appendix A. Due to the fact that no toxic chemical could be found in either dry or wet weather sampling the probability of a persistent toxicity problem in Spring Branch is unlikely.

When the Borden Chemical plant was in operation it discharged an aerated effluent that improved dissolved oxygen concentrations at monitoring station 5ASRN003.69. In addition, Borden Chemical used ground water for cooling purposes that was more alkaline than the water in Spring Branch resulting in higher pH values in the stream. After it was used for cooling, the wastewater from Borden Chemical was often warmer than the water in Spring Branch, so temperature values were higher at monitoring station 5ASRN003.69 prior to 2003.

Close inspection of the water quality data presented above reveals considerable differences between the upstream and downstream portions of Spring Branch. The upper section, which includes monitoring stations 5ASRN001.99, 5ASRN003.69, and 5ASRN003.82, exhibits most of the characteristics of swamp waters such as low pH (<6.0 std units) due to humic and fulvic acids, low dissolved oxygen and a brown tea color. In addition, stream flow in the upper portion of Spring Branch is a braided meandering pattern similar to other streams considered swamp waters. The most upstream benthic monitoring station, 5ASRN003.82, is at the headwaters of Spring Branch and it suffers from very low stream flows particularly in the fall. In addition, there is no defined stream channel. As a result, the use of the CPMI index is not appropriate at this station. Therefore, this station will not be considered in the remainder of the TMDL analysis. The lower portion of Spring Branch, from the Spring Branch Wastewater Treatment Facility discharge to the Blackwater River confluence, reveals a much larger stream with a single well-defined channel. This portion of Spring Branch receives excessive inputs of nutrients from the Spring Branch Wastewater Treatment Facility discharge and runoff from the surrounding area. The monitoring station downstream from Bryant Pond (5ASRN000.65) periodically has high pH values (>9.0 std units). This is an indication of severe eutrophication problems in the pond. In addition, monitoring station 5ASRN001.24 periodically has low dissolved oxygen concentrations (<4.0 mg/L).

2.6 Point Sources

There is only one active VPDES permitted discharge in the Spring Branch watershed. Table 2.27 and Figure 2.15 show current and former VPDES discharges.

Table 2.27 Point sources in the Spring Branch watershed.

VPDES Permitted Discharge	VPDES #	Permitted Flow (MGD)	Status
Sussex County Sanitary Authority – Spring Branch WTF	VA0061310	0.90	Active permit
Former Borden Chemical site	VA0004782	NA	Plant closed in 1/2001. Permit expired 9/13/2001.
Masonite	VAR540092	NA	Plant closed in 8/2003.

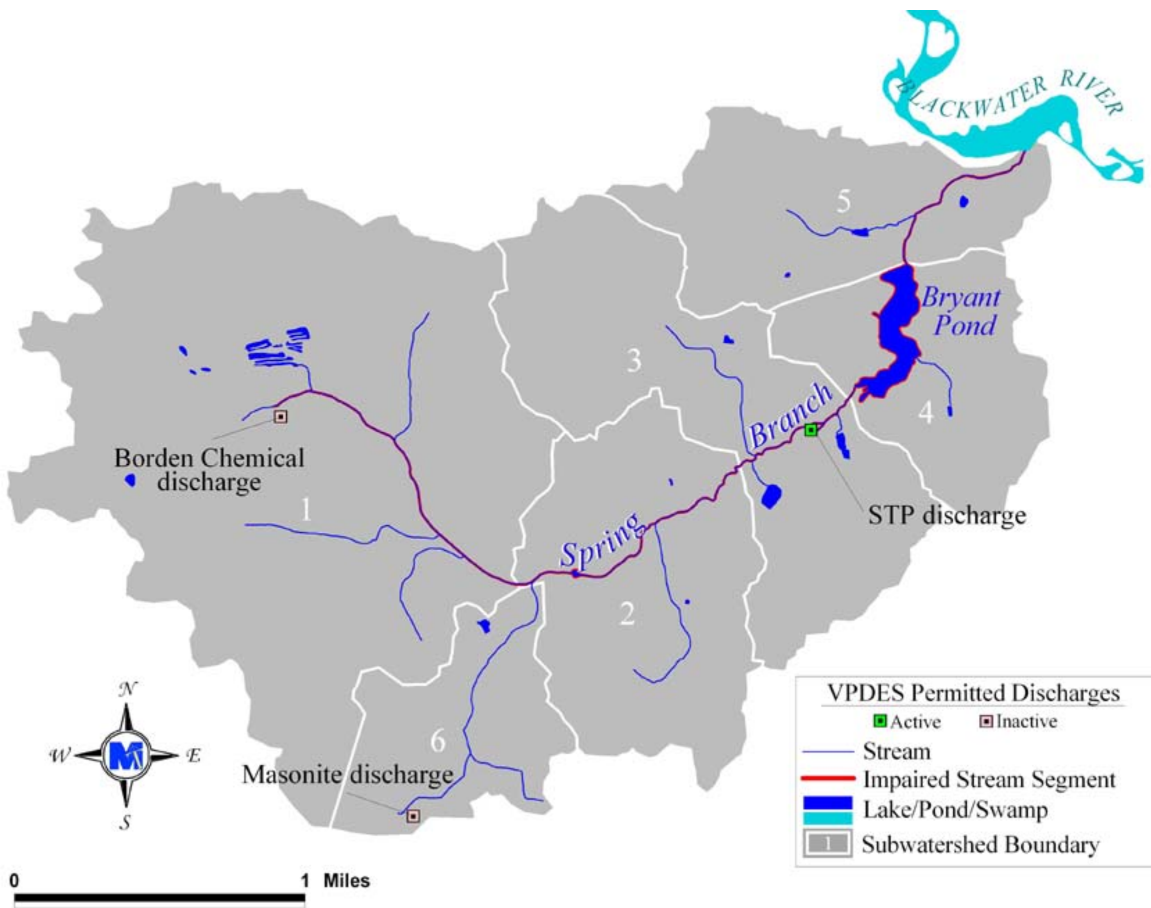

Figure 2.15 Current and former VPDES permitted discharges in the Spring Branch watershed.

A primary (provides minimal treatment) sewage treatment plant (STP) served the Town of Waverly from the 1930s until 1976. This STP was known to discharge large volumes of sewage solids that were documented to significantly impact Spring Branch. Following the passage of the Clean Water Act in 1972, wastewater discharges were required to upgrade to higher levels of treatment. A new, more advanced STP replaced the Waverly primary STP in 1976 (VA0061310). The new STP was significantly better, but it also suffered from periodic hydraulic overloads and discharged solids in excess of its permitted level. The treatment plant was expanded and upgraded and the newer STP (Spring Branch Wastewater Treatment Facility) began discharging on February 9, 2003. The design flow for the STP was increased from 0.35 (MGD) to 0.9 (MGD) and ownership was transferred to the Sussex County Service Authority (SCSA). The Spring Branch Wastewater Treatment Facility discharge is interconnected with several other STPs owned by the SCSA; during times of very high flows, some inflow can be diverted to these other STPs to prevent the loss of solids to the receiving stream. To date, there have been no VPDES permit violations.

Spurlock produced a urea formaldehyde resin in the watershed until August 1999, when the VPDES permit was modified to reflect Borden Chemical as the new owner. Borden operated the site until February 16, 2001, when all operations ceased.

Masonite was a particle board manufacturer that operated under VPDES permit VA0004022 until 1987 when its process wastewater was diverted to the Waverly STP. Masonite was then issued a general stormwater runoff permit. The plant ceased operations in August 2003 and the plant site is now occupied by another business whose wastewater is treated by the Spring Branch Wastewater Treatment Facility (VA0061310).

2.7 Additional Benthic Assessment Information

Figure 2.16 depicts the dominant family groups found at the four benthic monitoring stations on Spring Branch for the Fall 2004, Spring 2004 and, Spring 2005 sampling events. The graph indicates the differences between the upper and lower portions of Spring Branch.

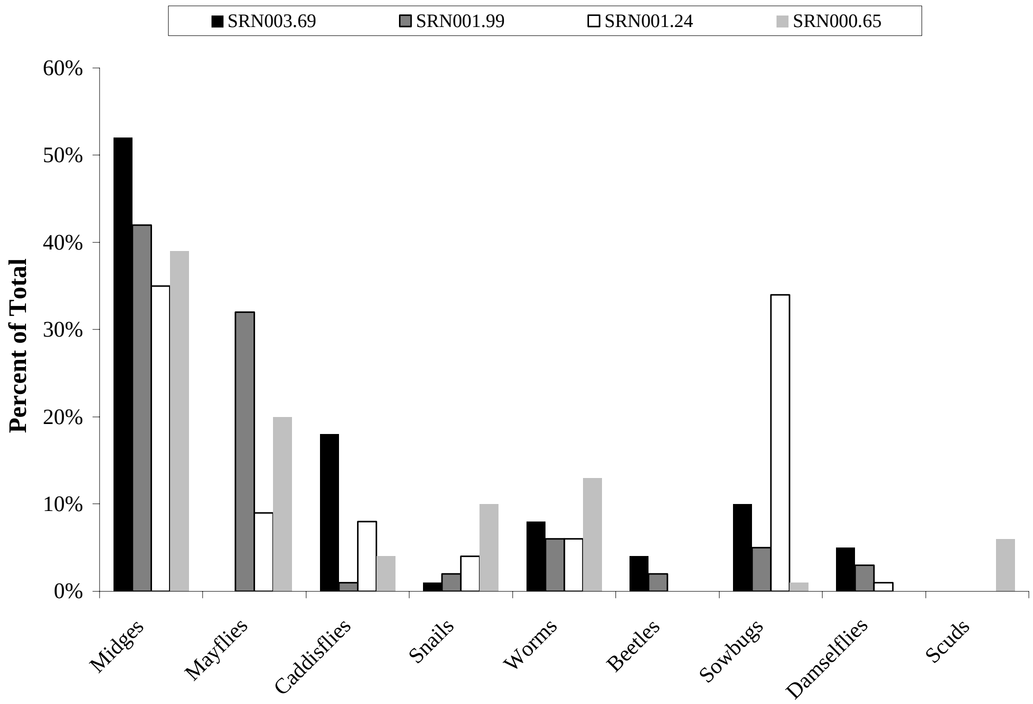

Figure 2.16 Dominant family groups at Spring Branch benthic monitoring stations, May 2004, November 2004 and May 2005.

The biggest difference among the four stations was at station 5ASRN001.99, which is near the transition between upper and lower Spring Branch. Mayflies were the dominant family at this station in all of the surveys and it had the highest average CPMI score (13). Pollution tolerant midges and sowbugs dominated the other three stations. The Fall 2004 results indicated higher percentages of mayflies at the other three monitoring stations, especially 5ASRN000.65. VADEQ biologists attribute this to higher than average stream flow during the summer months resulting from the remnants of four hurricanes that passed over the area. The impact of the increased stream flow and periodic flushing interrupted the algal growth process and actually allowed for some recovery. The Fall 2004 survey showed significant increases of mayflies at stations 5ASRN000.65 and 5ASRN001.24.

Figure 2.17 depicts the habitat values found at the four benthic monitoring stations for both of the 2004 as well as the spring 2005 sampling events.

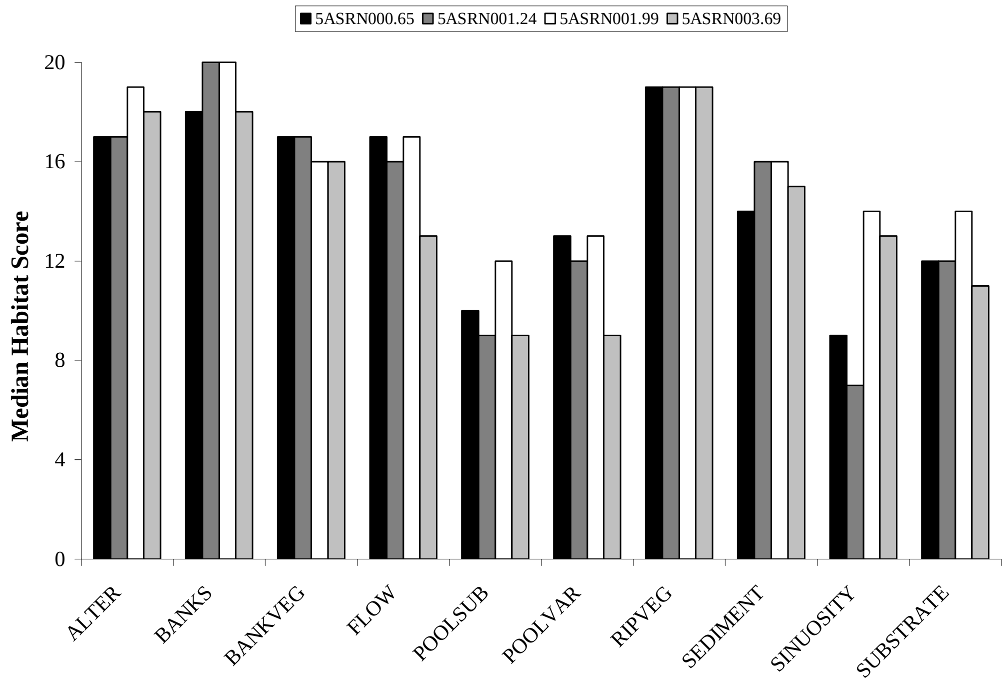

Figure 2.17 Median habitat scores at Spring Branch benthic monitoring stations (May 2004, November 2004 and May 2005).

The habitat metric that demonstrates the biggest difference between upper and lower Spring Branch is Channel Sinuosity. Lower Spring Branch had very low scores, indicating long straight sections with very few bends and sparse habitat. In contrast, upper Spring Branch had very good scores because of its meandering braided pattern.

Table 2.28 shows the results of field data collected during a joint site visit to Spring Branch by MapTech and VADEQ personnel from PRO on June 24, 2004. This table clearly shows the differences between upper and lower Spring Branch.

Table 2.28 Field parameters in Spring Branch collected by VADEQ on June 24, 2004.

Monitoring Station	Location*	DO mg/L	pH std units	Temperature Celsius	Conductivity µmhos/cm
5ASRN000.65	Lower	5.0	7.3	26	277
5ASRN001.24	Lower	7.4	7	24.6	520
5ASRN001.99	Upper	2.1	6.6	24.5	189
5ASRN003.69	Upper	3.6	6.2	22.6	89
5ASRN003.82	Upper	3.7	6.3	23.2	88

*Lower – Lower Spring Branch, Upper – Upper Spring Branch

The upper portion of Spring Branch had very low dissolved oxygen concentrations (below the minimum waters quality standard of 4.0 mg/L) and pH values were lower as well. The two downstream monitoring stations in the lower portion of Spring Branch had dissolved oxygen concentrations above the minimum water quality standard and had higher pH values. The DO concentrations measured at monitoring stations 5ASRN003.82, 5ASRN003.69, and 5ASRN001.99 were taken between 10:00 am and 11:15 am. The low DO concentrations at monitoring station 5ASRN003.82 are natural and not caused by a pollutant. The same can be said for monitoring station 5ASRN003.69, but it is possible that the periodic spikes in nitrogenous compounds could be exacerbating this natural condition. Similarly, monitoring station 5ASRN001.99, at the Rt. 653 Bridge, is still impacted by beaver dams and the large wetland area with excessive algal growth just upstream from it. It is not known if the excessive nutrients from the former Borden Chemical plant have an impact on the benthic organisms at this monitoring station. The dissolved oxygen concentration at monitoring station 5ASRN001.24 is artificially high and, according to VADEQ personnel, this is most likely due to the discharge of a highly aerated effluent from the Spring Branch Wastewater Treatment Facility.

This assessment reveals that, even though Spring Branch is a small stream, the four biological monitoring stations are impacted by different problems. Some of the problems are natural, but still influenced by human activities, and there is a significant difference between the upper and lower portions of Spring Branch. Another example is the benthic studies from 2004 and 2005 show there is a marked decrease in the quality of the benthic community at 5ASRN001.24 relative to 5ASRN001.99. In both Spring 2004 and Spring 2005, the benthic community at 5ASRN001.99 exhibited greater taxa richness (average of 15.5 families for 5ASRN001.99 vs. 9 families for 5ASRN001.24) and a higher percentage of mayflies (average of 27% for 5ASRN001.99 vs. 4.5% for 5ASRN001.24). The lower benthic scores at 5ASRN001.24 occur despite the fact that DO water quality standard violations are more frequent at 5ASRN001.99. Although the recent habitat scores for these stations are slightly lower for 5ASRN001.24, they are not sufficient to explain the observed differences in benthic communities. The most prominent difference in water chemistry between these two stations is total phosphorous, which rises dramatically from 5ASRN001.99 (median TP = 0.1 mg/L) to 5ASRN001.24 (median TP = 0.43), Figure 2.18. While there are also increases in nitrogen species from 5ASRN001.99 to 5ASRN001.24, they are less dramatic and unlikely to account for the observed benthic results since phosphorous is often the limiting nutrient in freshwater systems.

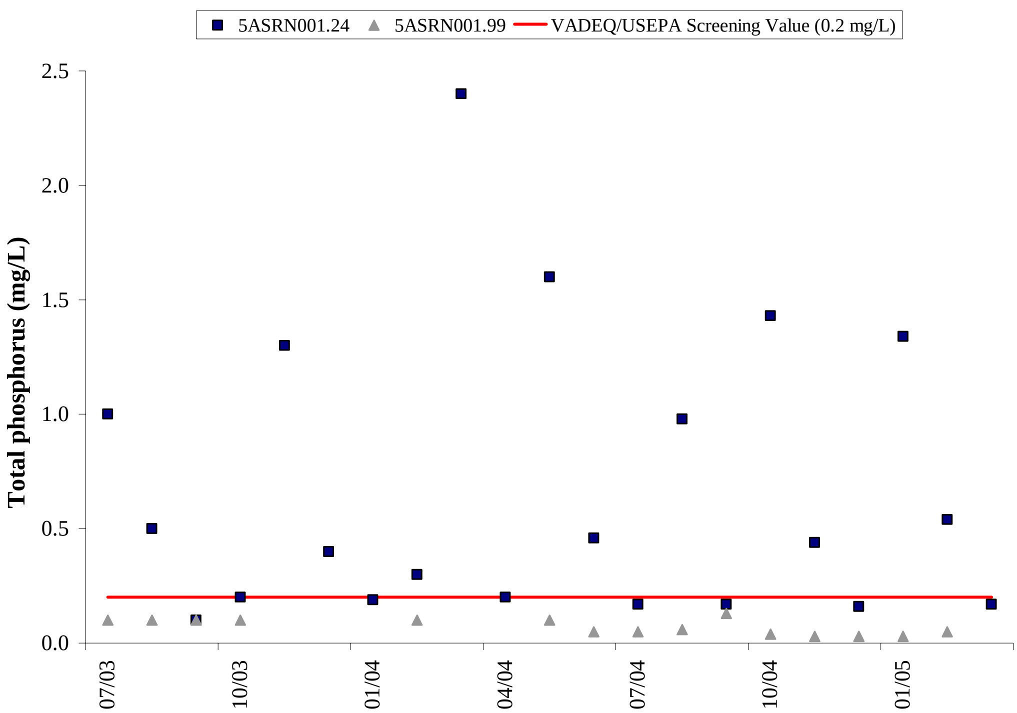

Figure 2.18 Total phosphorus concentrations at VADEQ monitoring stations 5ASRN001.24 and 5ASRN001.99.

3. BENTHIC STRESSOR IDENTIFICATION: TMDL ENDPOINT SELECTION

3.1 Background

Spring Branch is located in the Northeastern portion of Sussex County, Virginia. It is a second order stream in the Southeastern Plains ecoregion. While the dominant land use is forest, below Bryant Pond near its confluence with the Blackwater River, agriculture is more prevalent.

Ambient monitoring data from all five monitoring stations on Spring Branch were used in the stressor identification. The recent data record from these monitoring stations is from July 2003 through March 2005. Stations 5ASRN000.65 and 5ASRN003.69 had some historic data collected prior to June 1990. A subset of the historical data from 5ASRN003.69 was compared to the more recent data in Chapter 2. Scatter graphs are shown for all monitoring stations that have values exceeding a water quality standard or screening value or were considerably higher than a normal background value. If a parameter has no high values (values well above the expected normal range) at any of the monitoring stations, only the median values for the parameter are shown at each monitoring station. Scatter graphs for all of the parameters examined at each station are shown in Appendix B. Recent data was also collected on an unnamed tributary to Spring Branch (5AXFG000.04). This tributary received discharge from the former Borden Chemical plant when it was in operation. Where appropriate, high values from this site will also be discussed.

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not, but they usually do not provide enough information to determine the cause(s) of the impairment. The process outlined in EPA's *Stressor Identification Document* (EPA, 2000) was used to separately identify the most probable stressor(s) for Spring Branch. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Land use data, as well as a visual assessment of conditions along the stream, provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, organic matter, and temperature. The results of the stressor analysis for Spring Branch are divided into three categories:

> **Non-Stressor**: The stressor(s) with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors (Table 3.1).
>
> **Possible Stressor**: The stressor(s) with data indicating possible links, but inconclusive data were considered to be possible stressors (Table 3.2).
>
> **Most Probable Stressor**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s) (Table 3.4).

3.2 Non-Stressors

Table 3.1 Non-Stressors in Spring Branch.

Parameter	Location in Document
Temperature	Section 3.2.1

3.2.1 Temperature

The maximum temperature recorded in Spring Branch was 30.28^{o} $^{(}$Celsius) at monitoring station 5ASRN000.65. This value is below the current maximum water quality standard of 32^{o} (Celsius). Median temperature values for all five monitoring stations are shown in Figure 3.1. Temperature was eliminated as a potential stressor.

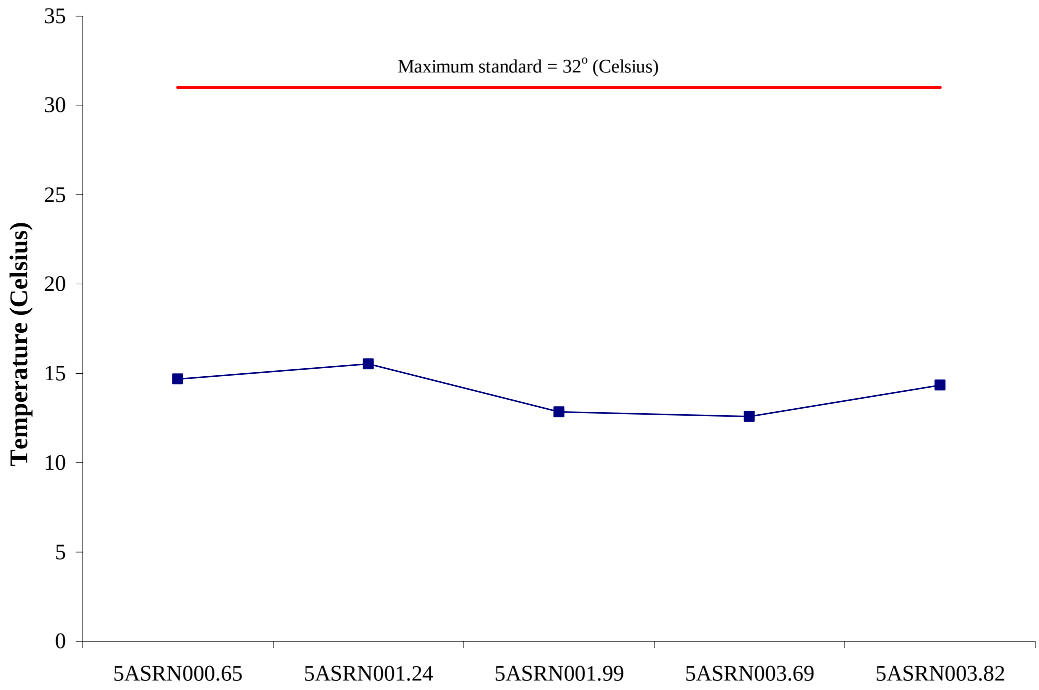

Figure 3.1 Temperature values for VADEQ monitoring stations on Spring Branch.

3.3 Possible Stressors

Table 3.2 Possible Stressors in Spring Branch.

Parameter	Location in Document
Organic Matter	Section 3.3.1
Sediment	Section 3.3.2
Toxics	Section 3.3.3

3.3.1 Organic Matter

Two parameters measured in Spring Branch can be used to determine if organic matter in the stream might be at concentrations high enough to impact the benthic macroinvertebrate community: BOD_5 and TKN values. Biochemical oxygen demand (BOD_5) can provide an indication of how much dissolved organic matter is present. Only monitoring station 5ASRN000.65 had a high BOD_5 concentration (Figure 3.2). Median BOD_5 concentrations are within acceptable levels (Figure 3.3). The unnamed tributary to Spring Branch (5AXFG000.04) had two high BOD_5 concentrations: 59 mg/L on 1/14/2004 and 21 mg/L on

3/15/2004. Total Kjeldahl nitrogen (TKN) measures both organic nitrogen and ammonia. High TKN concentrations of 10.2 mg/L and 12.5 mg/L were measured at monitoring stations 5ASRN001.24 and 5ASRN000.65, respectively (Figures 3.4 and 3.5). These values are more than 10 times higher than what is considered to be the typical background concentration for streams with swamp characteristics. The source of the high TKN values at 5ASRN000.65 is the breakdown of excess organic matter from algae blooms in Bryant Pond. High TKN concentrations at 5ASRN001.24 are probably due to the breakdown of organic matter and the discharge from the Spring Branch Wastewater Treatment Facility. Median TKN concentrations for all five monitoring stations are shown in Figure 3.6. Median TKN concentrations are higher at all five Spring Branch monitoring stations than a typical background median concentration of 0.6 mg/L for streams with swamp-like characteristics. The historic data comparison shown in Chapter 2 demonstrated that there had been improvement in in-stream TKN concentrations since the Borden Chemical plant closed but, periodically, there are still high spikes (4.66 mg/L on 7/22/2003). It is clear, even from the limited amount of data, that the amounts of organic nitrogen in Spring Branch are occasionally higher than what is considered a normal background concentration both upstream and downstream of the former Borden Chemical site. High TKN concentrations in the upper portion of Spring Branch are also the result of the breakdown of organic matter and periodic runoff from the former Borden Chemical plant site. Monitoring station 5AXFG000.04 on the unnamed tributary to Spring Branch had two high TKN concentrations: 12.0 mg/L on 8/5/2003 and 10.1 mg/L on 3/15/2004.

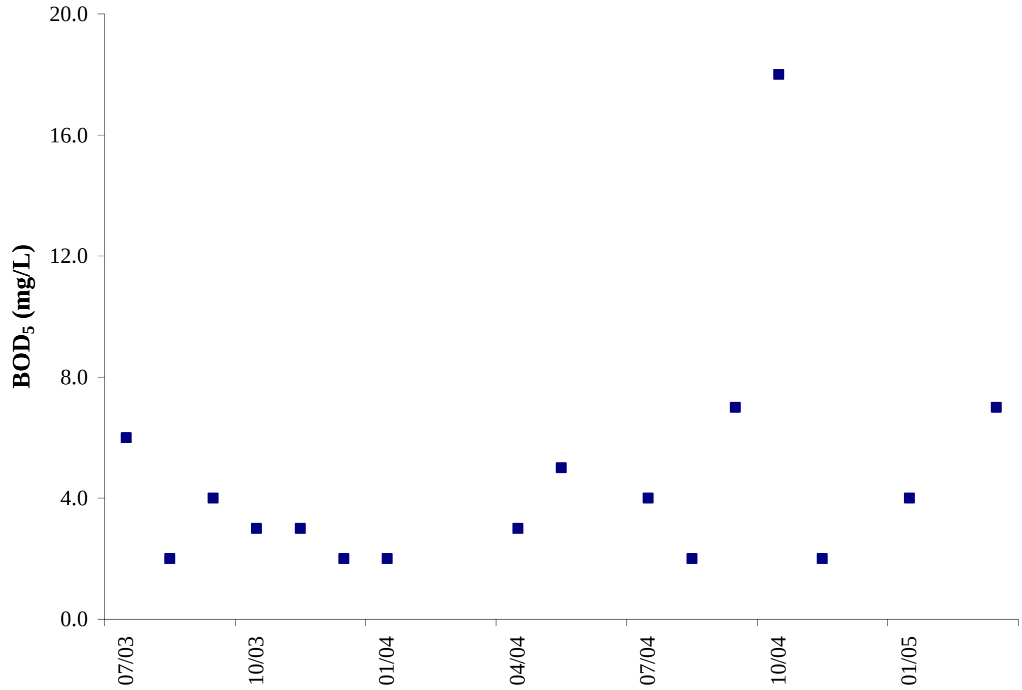

Figure 3.2 BOD5 concentrations at VADEQ monitoring station 5ASRN000.65.

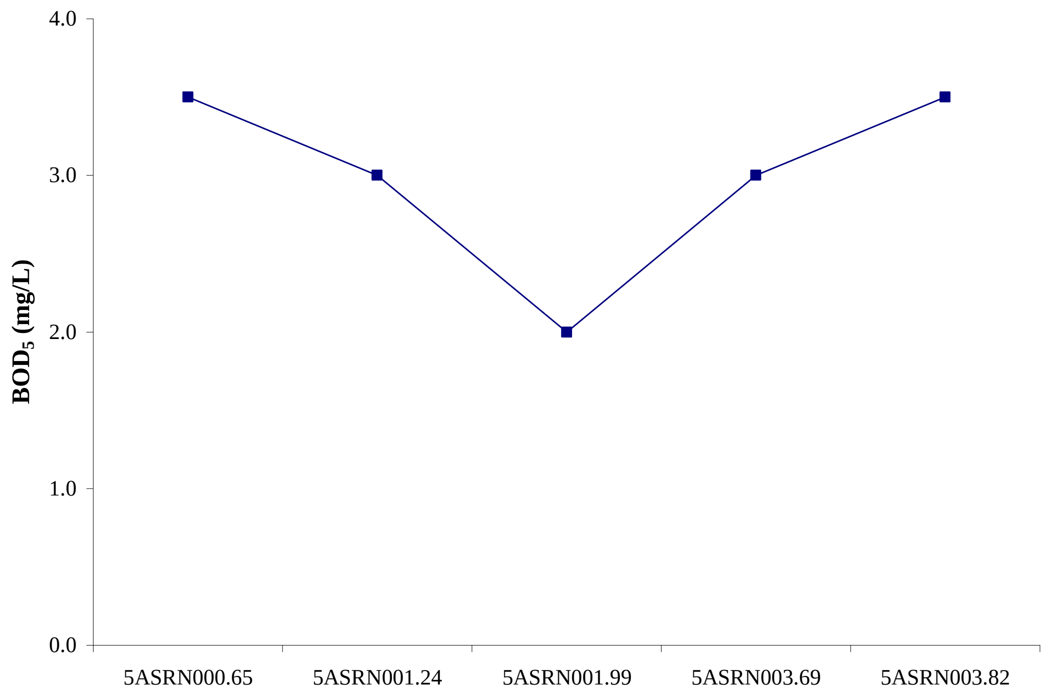

Figure 3.3 Median BOD5 values at VADEQ monitoring stations on Spring Branch.

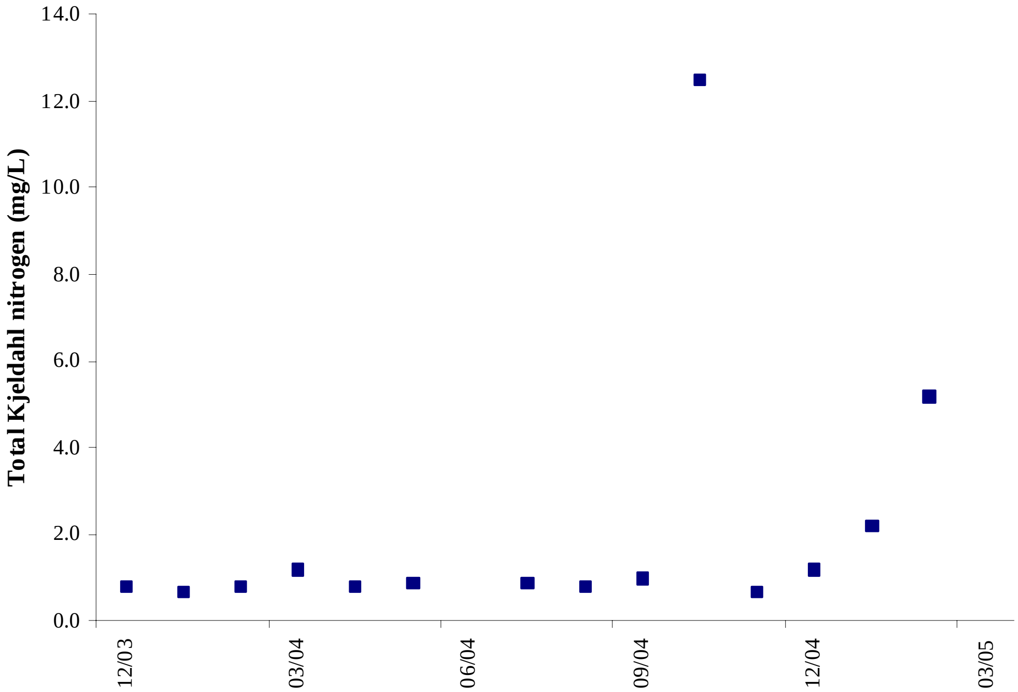

Figure 3.4 TKN concentrations at VADEQ monitoring station 5ASRN000.65.

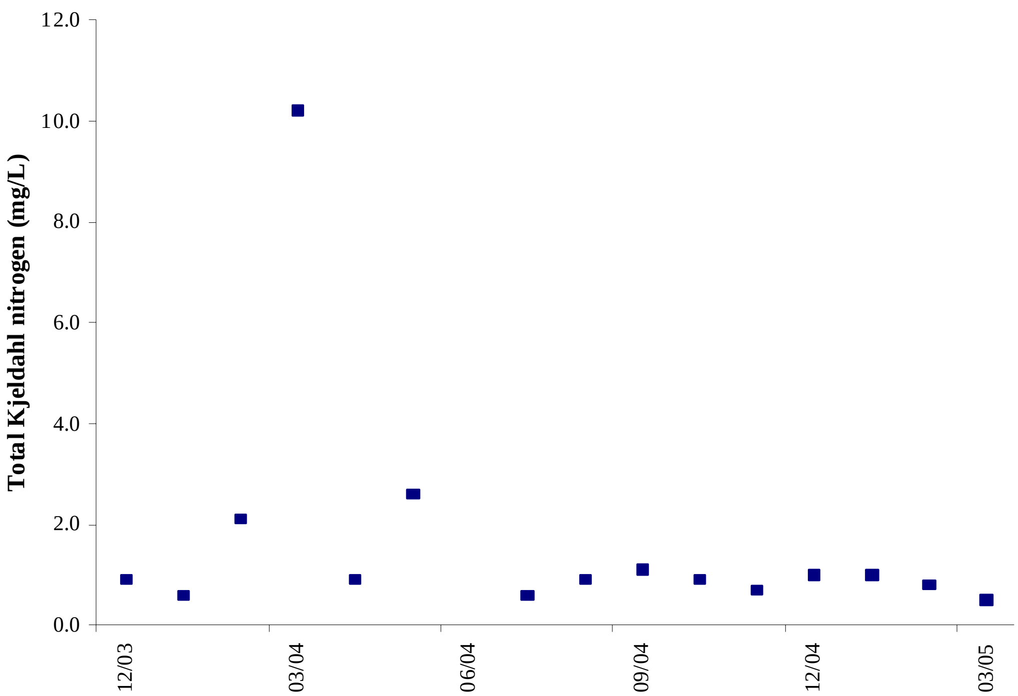

Figure 3.5 TKN concentrations at VADEQ monitoring station 5ASRN001.24.

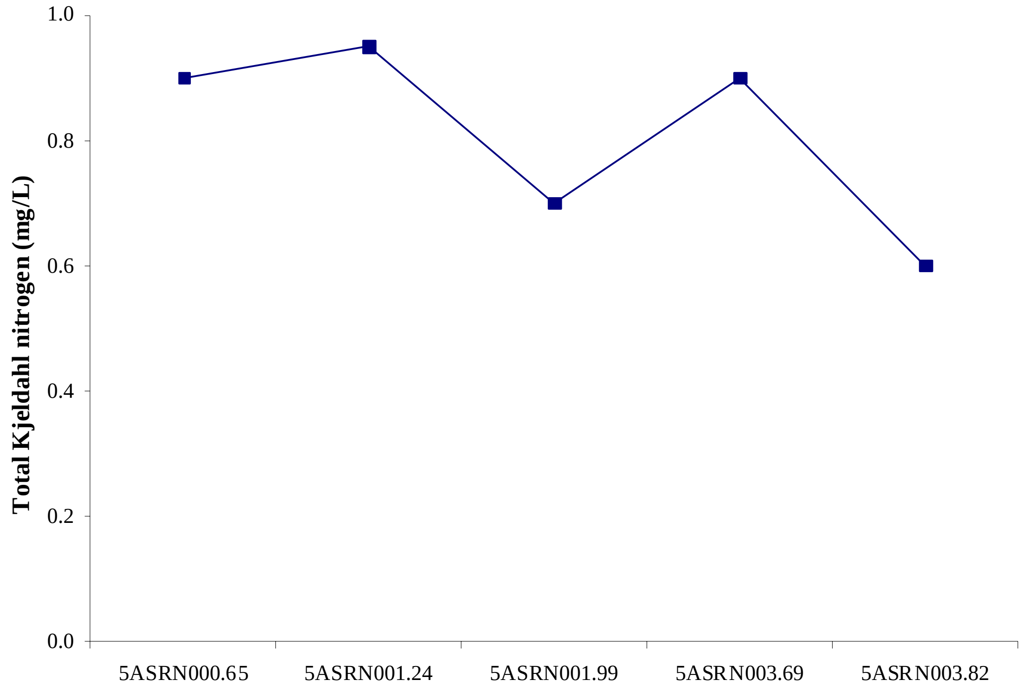

Figure 3.6 Median TKN concentrations at VADEQ monitoring stations on Spring Branch.

The chemical data indicates that organic matter may be too high in Spring Branch. This is not surprising given the multiple beaver dams on the stream. The impounded areas behind the dams trap leaves and other debris, which break down resulting in periodically high organic matter concentrations. In addition, Spring Branch is a low gradient stream and flows very slowly. The upper portion of the stream is very swamp-like in nature. Therefore, organic matter is considered a possible stressor.

3.3.2 Sediment

The values for habitat collected during 2004 do not support sediment as a possible stressor. In fact, the sediment scores for all four impaired monitoring stations on Spring Branch were in the optimal and suboptimal categories.

The only chemical parameter directly related to sediment in the recent monitoring data was total suspended solids (TSS). Figures 3.7 through 3.11 show TSS concentrations at all five monitoring stations. There were occasional spikes in TSS concentrations at every monitoring station (*e.g.,* 214 mg/L at 5ASRN003.69). The 2004 and 2005 habitat data presented in

Chapter 2 (Table 2.15) for VADEQ benthic monitoring station 5ASRN003.69 indicated that sediment was not a serious problem. Median TSS concentrations at all five monitoring stations are shown in Figure 3.12. Dead algae and fine amounts of organic matter that accumulated behind the beaver dams probably caused the spikes in TSS. Sediment is considered a possible stressor.

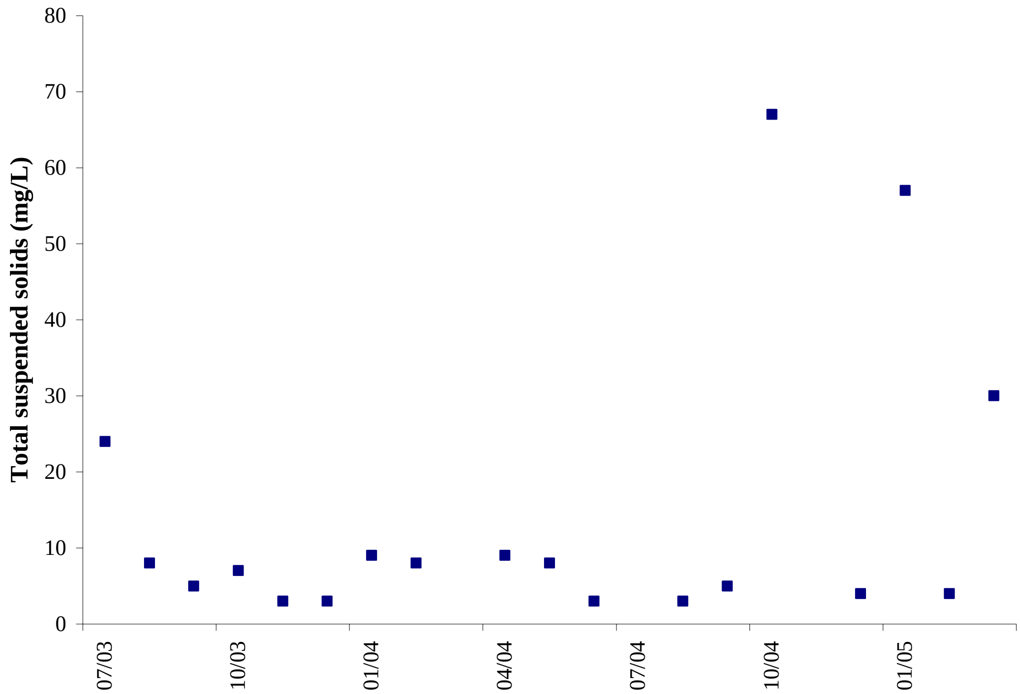

Figure 3.7 TSS concentrations at VADEQ monitoring station 5ASRN000.65.

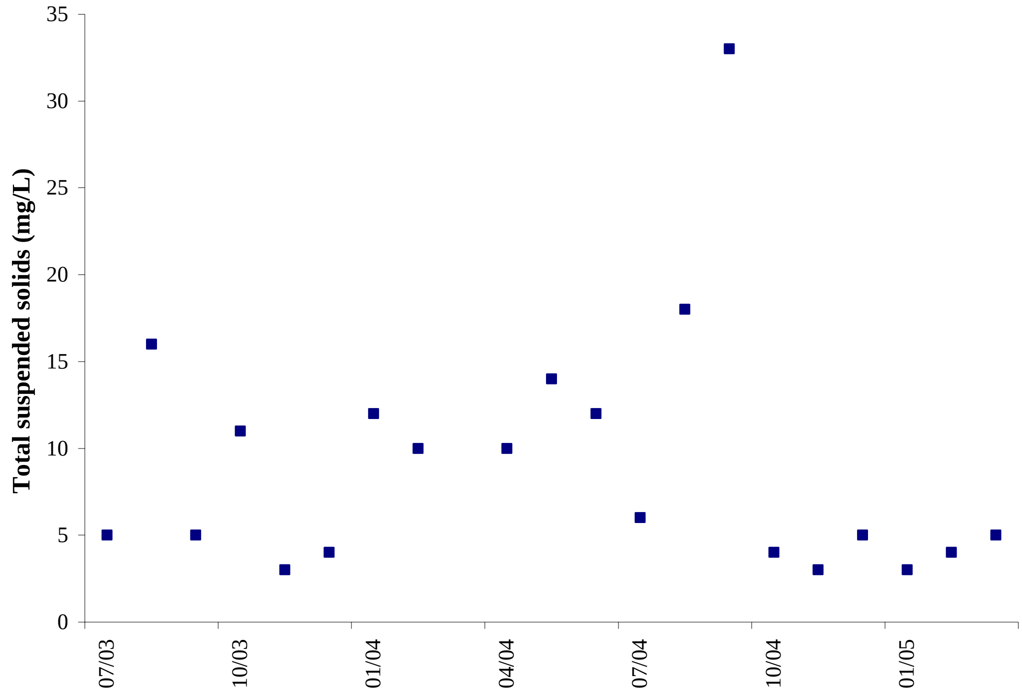

Figure 3.8 TSS concentrations at VADEQ monitoring station 5ASRN001.24.

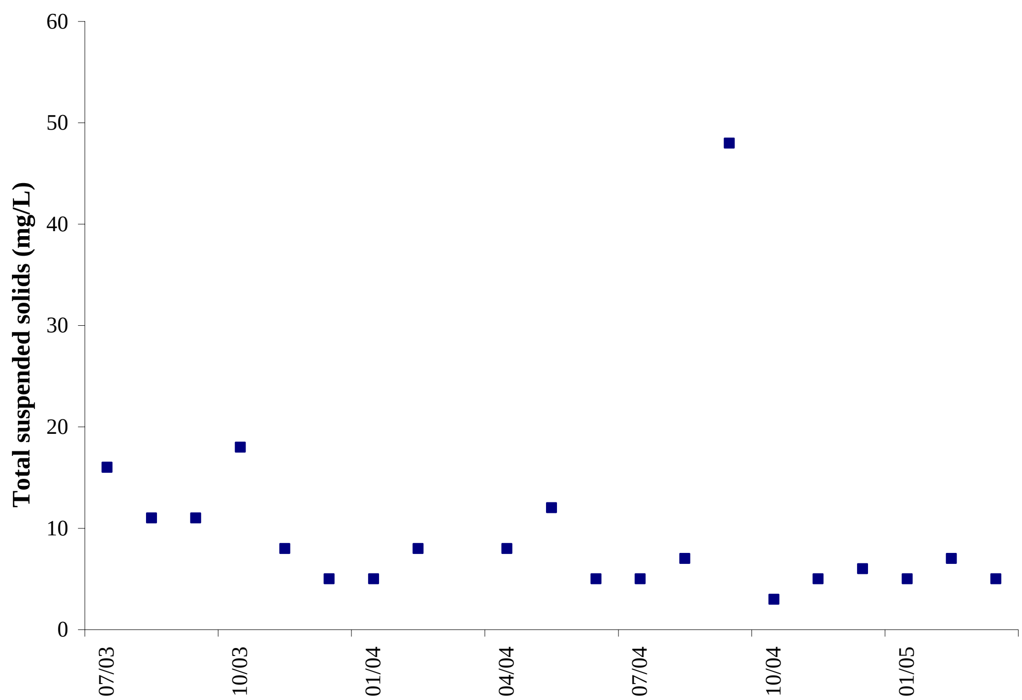

Figure 3.9 TSS concentrations at VADEQ monitoring station 5ASRN001.99.

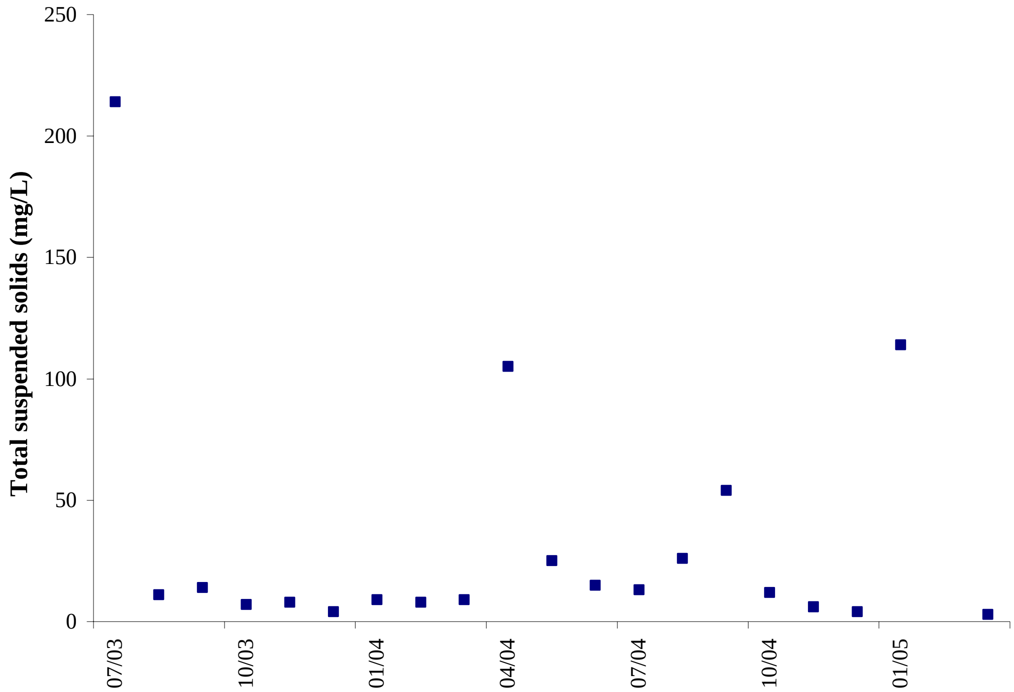

Figure 3.10 TSS concentrations at VADEQ monitoring station 5ASRN003.69.

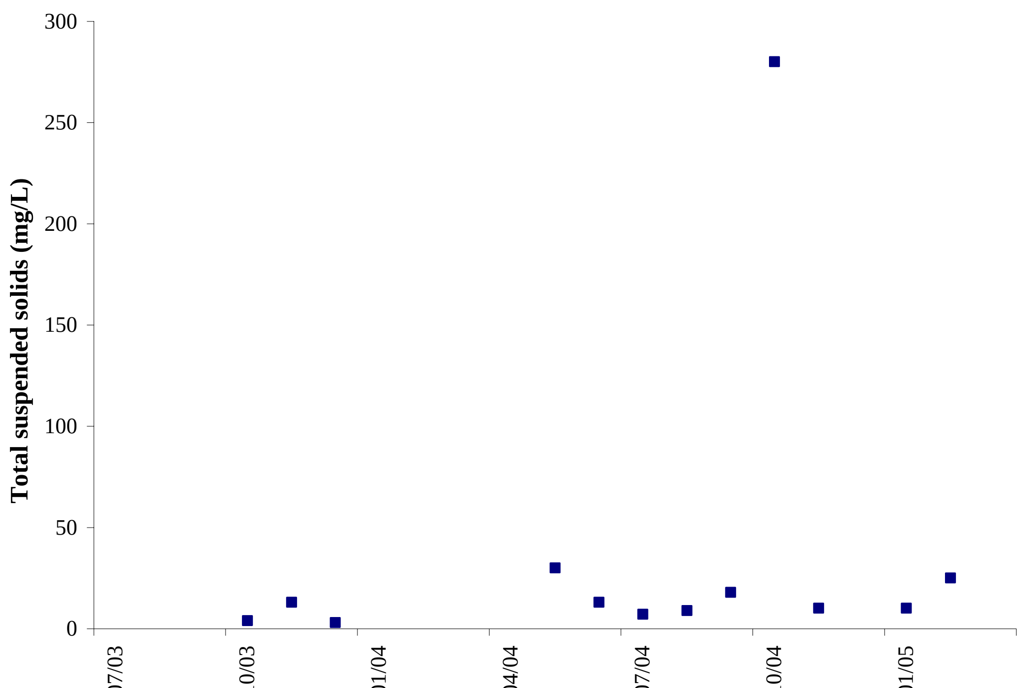

Figure 3.11 TSS concentrations at VADEQ monitoring station 5ASRN003.82.

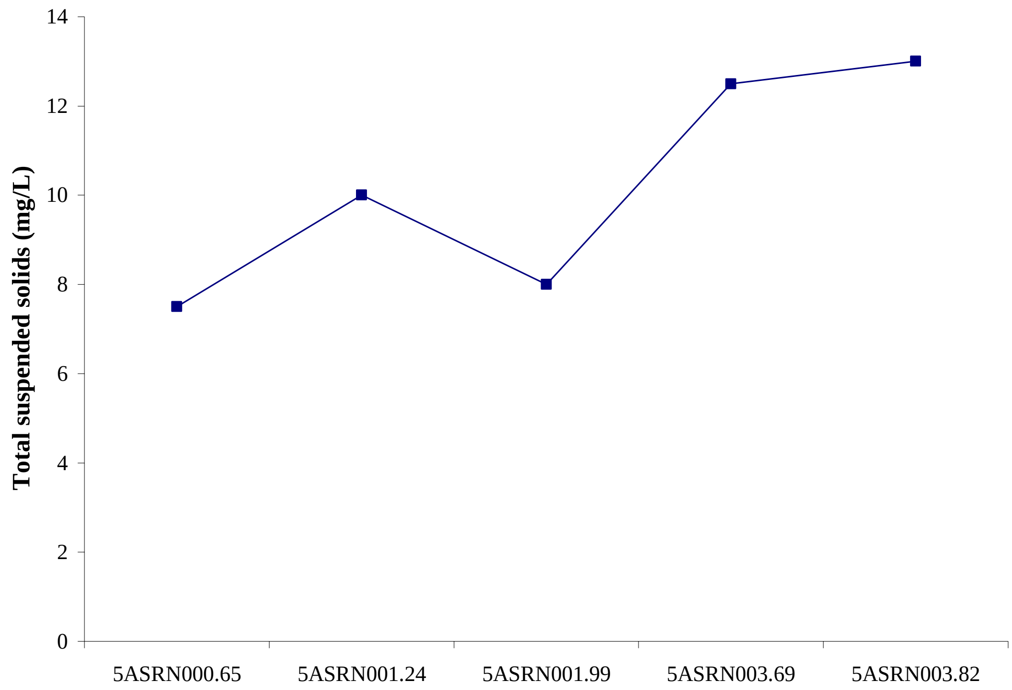

Figure 3.12 TSS median concentrations at VADEQ monitoring stations on Spring Branch.

3.3.3 Toxics

The only toxic parameter sampled in Spring Branch on a continual basis since 1990 was total ammonia; none of the monitoring stations exceeded either the chronic or acute water quality standard. Figure 3.13 shows the median total ammonia concentrations for all five monitoring stations on Spring Branch. Station 5ASRN003.69 had historically high ammonia levels but the concentrations measured since 1990 are well below water quality standards.

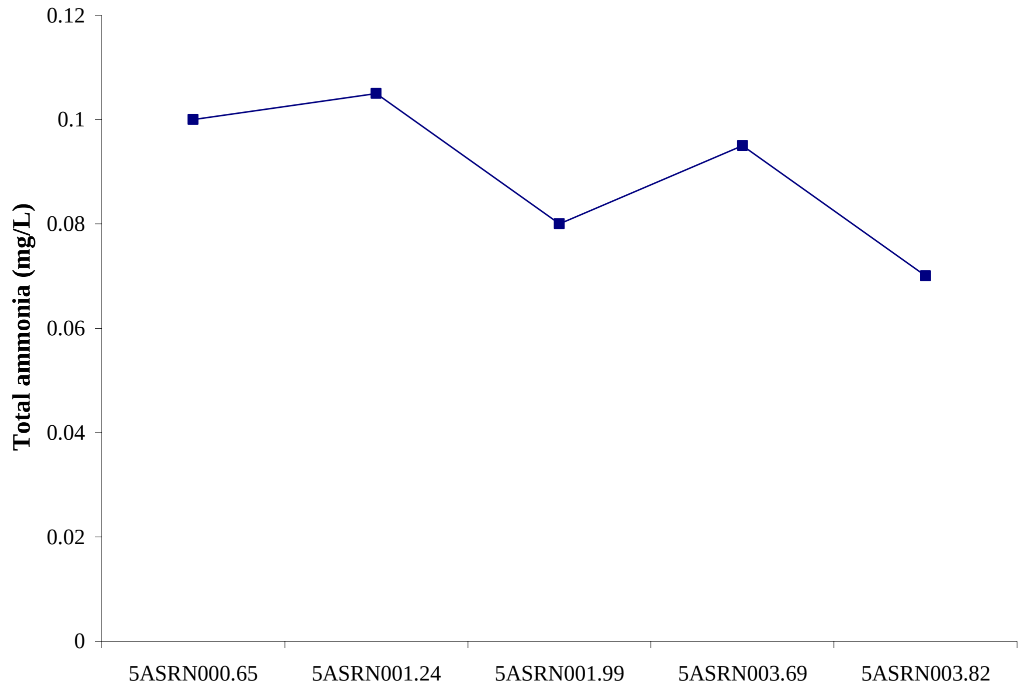

Figure 3.13 Median total ammonia concentrations at VADEQ monitoring stations on Spring Branch.

Figures 2.13 and 2.14 documented acute ammonia water quality standard violations in the early 1980s and chronic standard violations throughout the 1980s. Monitoring station 5AXFG000.04 (on the unnamed tributary that formerly received the Borden Chemical discharge) had an ammonia concentration of 6.1 mg/L on 8/5/2003. On November 2, 2004, samples were collected from the three upstream monitoring stations on Spring Branch for toxicity testing at EPA's Wheeling, West Virginia laboratory. On November 16, 2004, samples were collected at the two downstream monitoring stations and from Bryant Pond. Table 3.3 shows the results of the tests.

Table 3.3 Spring Branch November 2004 Toxicity Testing Results.

Station	Date	Toxicity Found	Result
5ASRN000.65	11/16/2004	Yes	Fathead Minnow Acute Effect
Bryant Pond[1]	11/16/2004	Yes	Fathead Minnow Acute Effect
5ASRN001.24	11/16/2004	No	None
5ASRN001.99	11/2/2004	Yes	Fathead Minnow Acute & Chronic Effects
5ASRN003.69	11/2/2004	Yes[2]	Fathead Minnow Acute & Chronic Effects

[1] 5ASRN000.66
[2] The conductivity in the sample was below 100 µmhos/cm, which can lead to an inaccurate result.

A single toxicity test is not enough to confirm a chronic toxics problem; however, as discussed in Chapter 2 (Section 2.5.3), ground water contamination has been found at the former Borden Chemical site located just upstream from monitoring station 5ASRN003.69. Ground water tests conducted in June 2003 showed that ammonia concentrations in MW2 were more than 3,000 times higher than Virginia's ground water standard of 0.025 mg/L (9 VAC 25-280-10). Sampling was repeated in October 2003 and the ammonia concentration in MW2 was 1,800 times greater than the ground water standard. In addition, nitrite/nitrate-nitrogen concentrations in MW2 were also high. Chloroform was detected in MW3, but it was below the MCL. Carbon disulfide was detected in MW2, but an actual concentration was too low to be estimated. As noted in Section 2.5.3, VADEQ sampled during dry and wet weather for numerous toxic organic compounds and they were not able to isolate a likely suspect. At the present time no linkage exists between the benthic metrics at VADEQ station 5ASRN003.69 and a toxicity problem in upper Spring Branch. Therefore, toxics are considered possible stressors.

3.4 Most Probable Stressors

Although Spring Branch is a very small stream, it has stressors that affect it differently at the four benthic monitoring stations. Table 3.4 lists the stations along with the most probable stressor and the possible source(s) of the stressor.

Table 3.4 Probable Stressors in Spring Branch.

Probable Stressor	Location in Document	Benthic Stations Affected	Possible Sources
High pH in Lower Portion	Section 3.4.1	Lower Portion - 5ASRN000.65	Lower Portion - Severe Eutrophication in Bryant Pond.
Nutrients/Dissolved oxygen	Section 3.4.2	Upper Portion - 5ASRN003.69 5ASRN001.99 Lower Portion - 5ASRN001.24 5ASRN000.65	Upper Portion - Natural swamp water and beaver dam impoundments. NPS nutrient runoff from former manufacturing site. Lower Portion - Nutrients from runoff and the STP discharge. Natural from beaver dam impoundments and swamp-like characteristics.

3.4.1 pH

Field pH values violated maximum water quality standards at one of the five ambient monitoring stations (Figure 3.14). In the lower portion of Spring Branch at monitoring station 5ASRN000.65 (located just below Bryant Pond), two out of 21 samples exceeded the maximum standard of 9.0 standard units (both values were 9.1). Algal growth in the pond results in high pH values measured during the day.

In addition, the eutrophication problem in the pond is quite severe. For example, a dissolved oxygen concentration of 0.65 mg/L was measured in July of 2004 and, in subsequent monitoring a value of 18.0 mg/L was measured in March 2005 indicating considerable algal activity. The March 2005 high dissolved oxygen reading corresponded to a 169% saturation, which indicates an algal bloom in progress. Algae go through the process of respiration during the day and use sunlight and carbon dioxide (CO_2) to produce energy. A by-product of this process is oxygen. The source of the CO_2 is from the air and water. The uptake of dissolved CO_2 from the water results in higher pH. At night when algae respire, they take up the available dissolved oxygen from the water, which lowers dissolved oxygen concentrations. At the same time, CO_2 is produced and the pH is lowered overnight. Although there were no extremely high or low pH values, the frequency with which water quality standard violations occur has the potential to chronically stress macroinvertebrates. High pH and dissolved oxygen deficits are the most serious algal related problems affecting aquatic life support in rivers and streams (Dodds and Welch, 2000).

In February 2004 the Virginia Water Quality Standards were modified and the streams in the Blackwater River watershed were given a special Class VII designation. This designation recognized that much of the watershed was characterized by swamps and may need site-specific temperature and dissolved oxygen standards. The minimum pH standard was lowered to 4.3 std units and the maximum standard remained 9.0 std units.

Figure 3.15 shows the median field pH values for all five monitoring stations. Based on the pH maximum water quality standard violations at VADEQ monitoring station 5ASRN000.65, pH is considered a probable stressor.

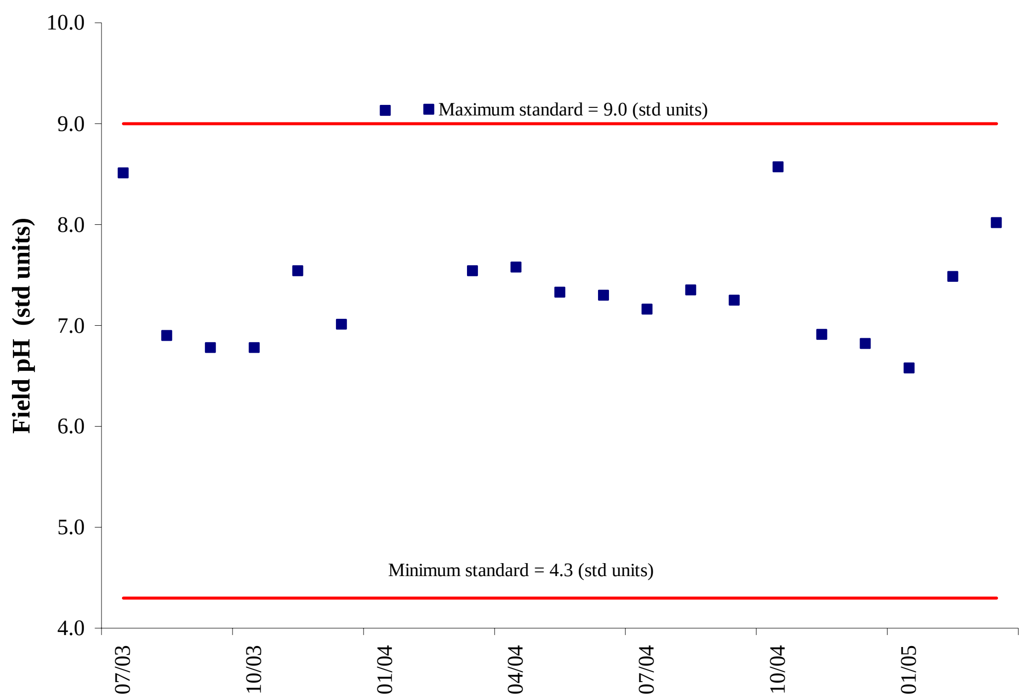

Figure 3.14 Field pH data at station 5ASRN000.65.

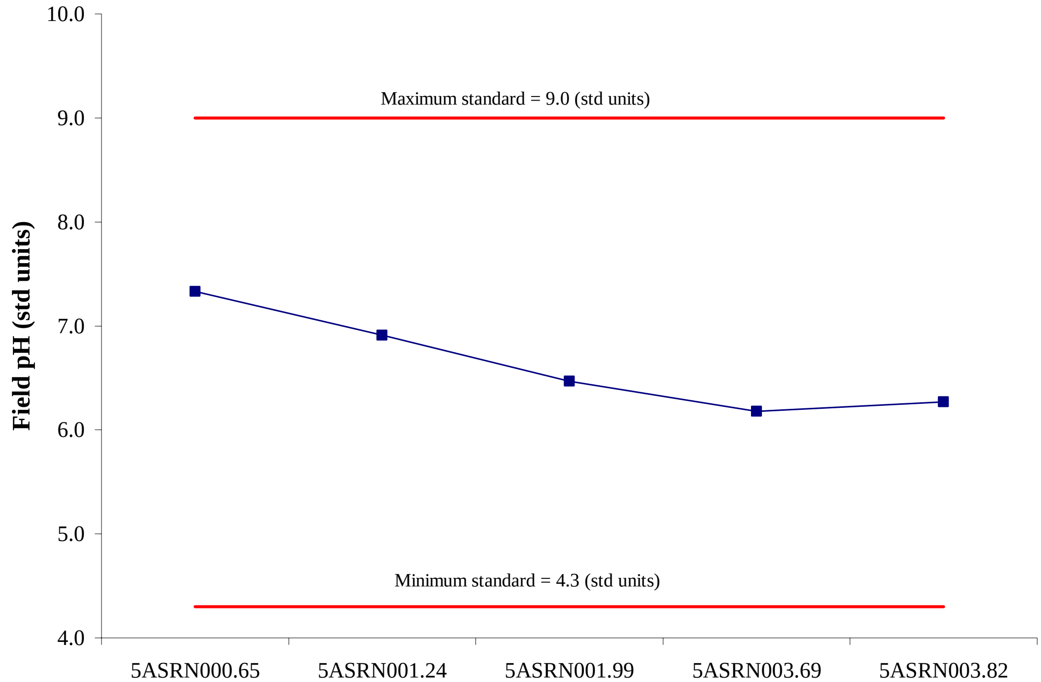

Figure 3.15 Median field pH values for VADEQ monitoring stations on Spring Branch.

3.4.2 Nutrients and Low Dissolved Oxygen

Four of the five ambient water quality monitoring stations had dissolved oxygen (DO) concentrations below the minimum water quality standard of 4.0 mg/L (Figures 3.16 through 3.19). Table 3.5 shows the actual concentrations and dates of the violations. As noted in section 3.4.1 above, the Blackwater River watershed is now in a special swamp waters classification VII. Class VII waters will be assigned site-specific DO water quality standards. The VADEQ is planning to start this process in 2006. Therefore, some of the values in Table 3.5 may not be lower than the new site-specific standard when it is adopted. The only station that did not violate the DO standard was 5ASRN000.65, downstream of Bryant Pond. This station is influenced by severe algal growth in Bryant Pond and no dissolved oxygen measurements were made earlier than 11:15 am. If DO was measured in the early morning hours before daylight, it is possible that some concentrations would be below the current water quality standard. In addition, the station is immediately downstream of the overflow from the dam. There is an eight-foot drop from the top of the impoundment to the stream and some re-aeration occurs. Figure 3.20 shows the median dissolved oxygen concentrations for all five VADEQ monitoring stations on Spring Branch. Two stations had values below 1.0 mg/L (5ASRN001.99 and 5ASRN003.69). Very low dissolved oxygen values have a negative impact on the biological community within a flowing stream.

Table 3.5 Dissolved oxygen minimum water quality standard* violations in Spring Branch.

STATION	DATE	DO (mg/L)
5ASRN001.24	7/22/03	2.88
5ASRN001.99	9/25/03	0.84
5ASRN001.99	8/5/03	3.40
5ASRN001.99	9/25/03	2.76
5ASRN001.99	5/11/04	3.08
5ASRN001.99	6/24/04	2.08
5ASRN001.99	7/19/04	3.03
5ASRN001.99	8/25/04	1.92
5ASRN001.99	10/12/04	2.58
5ASRN003.69	7/22/03	0.66
5ASRN003.69	9/25/03	3.42
5ASRN003.69	5/11/04	3.14
5ASRN003.69	6/24/04	3.60
5ASRN003.69	7/19/04	3.40
5ASRN003.69	8/25/04	3.85
5ASRN003.69	10/12/04	3.72
5ASRN003.82	5/11/04	3.21
5ASRN003.82	6/24/04	3.72
5ASRN003.82	10/12/04	2.67

* The current water quality standard is 4.0 mg/L

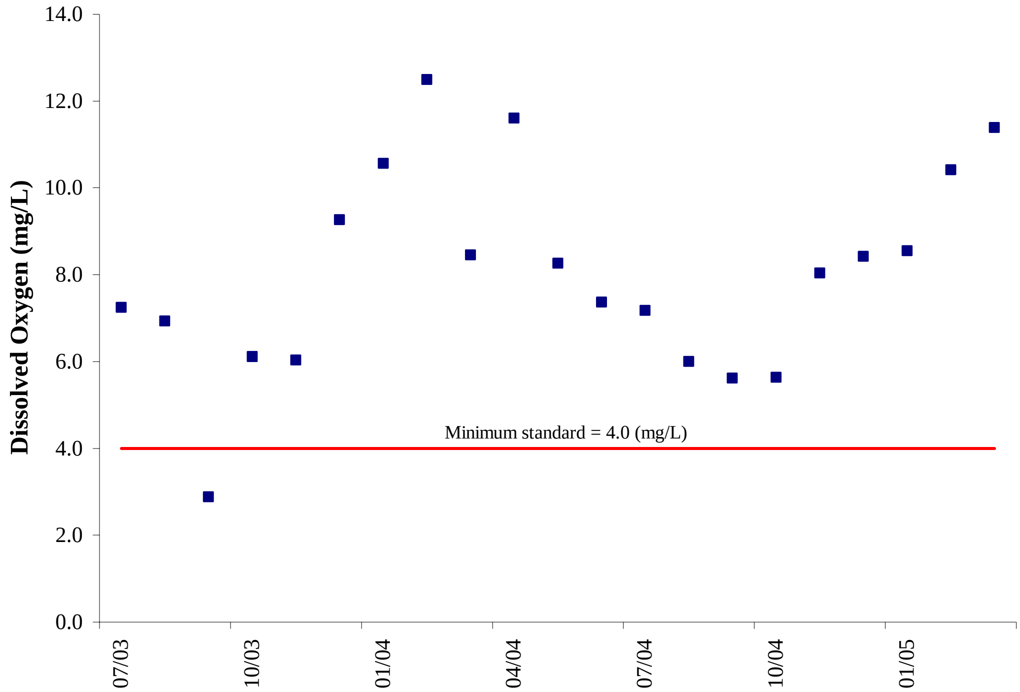

Figure 3.16 Dissolved oxygen concentrations at station 5ASRN001.24.

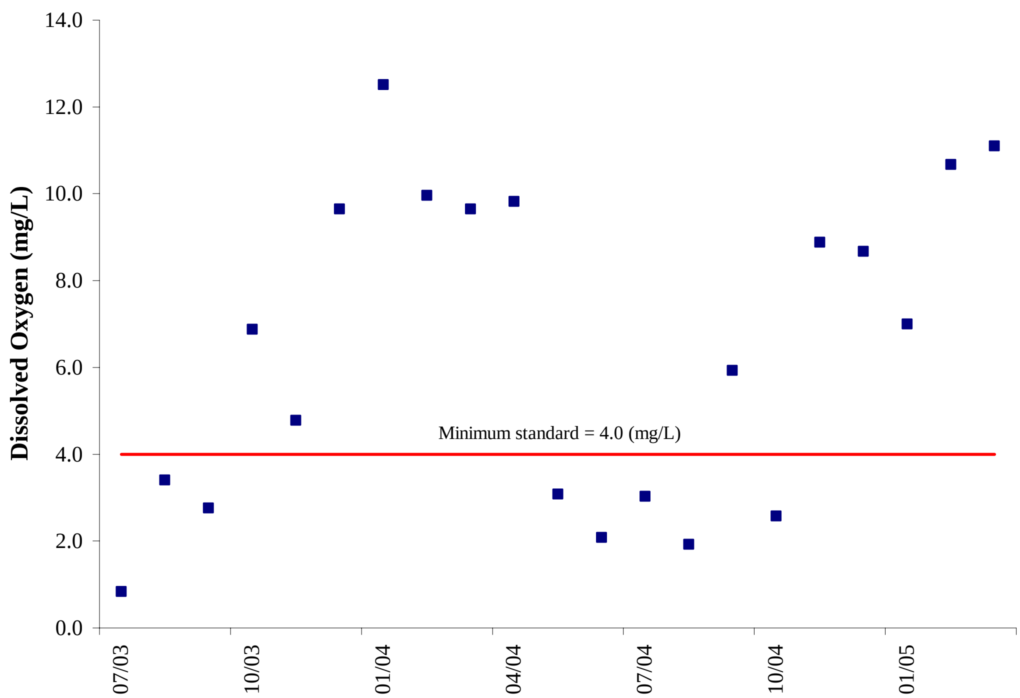

Figure 3.17 Dissolved oxygen concentrations at station 5ASRN001.99.

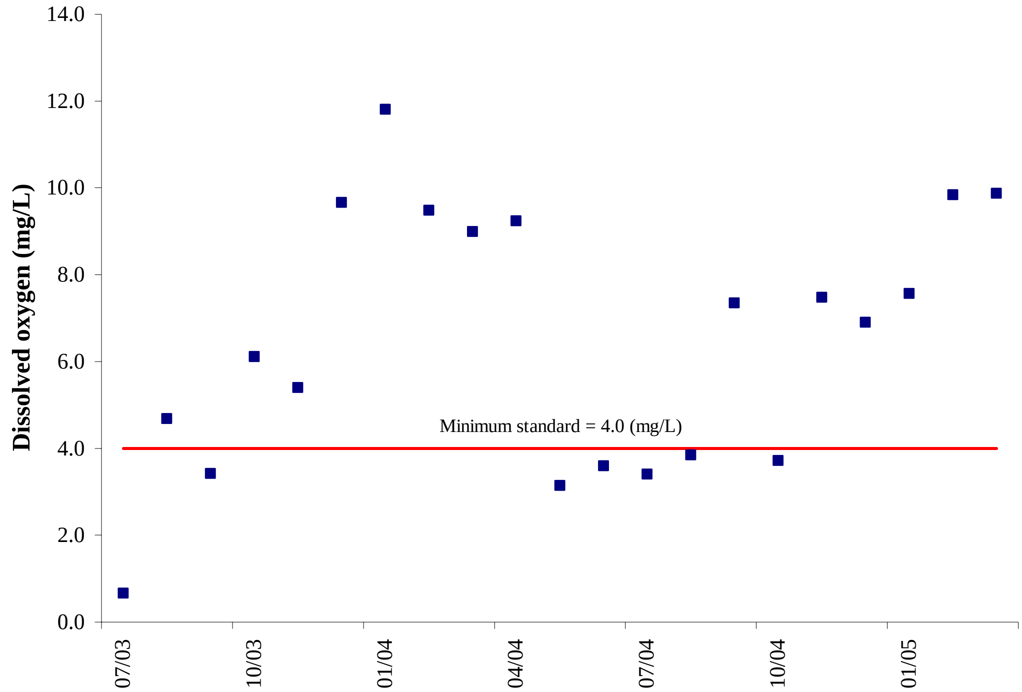

Figure 3.18 Dissolved oxygen concentrations at station 5ASRN003.69.

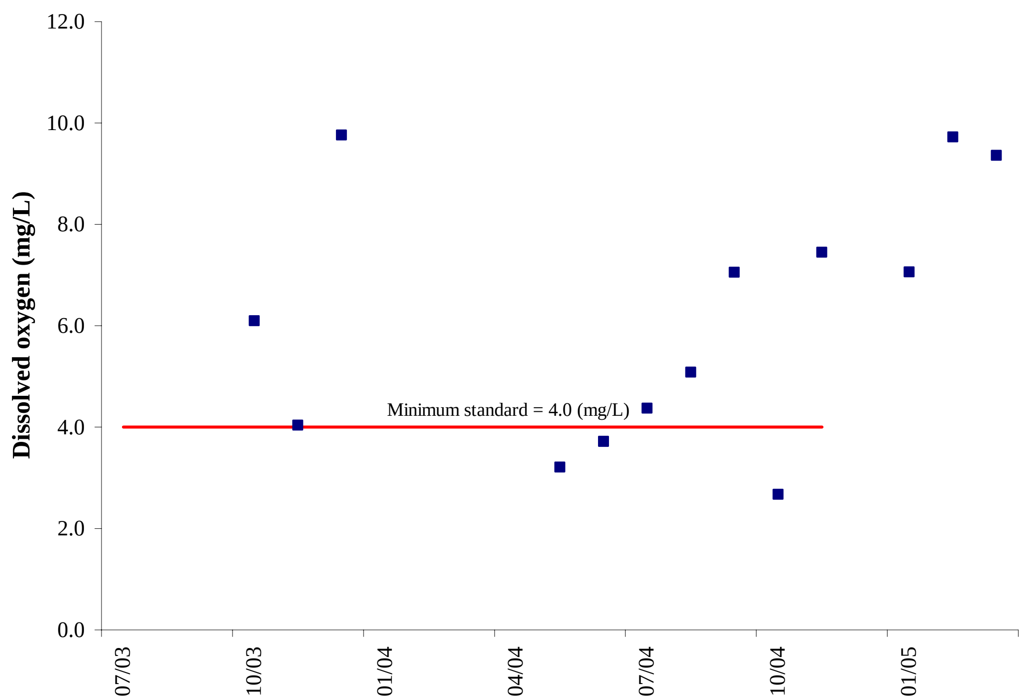

Figure 3.19 Dissolved oxygen concentrations at station 5ASRN003.82.

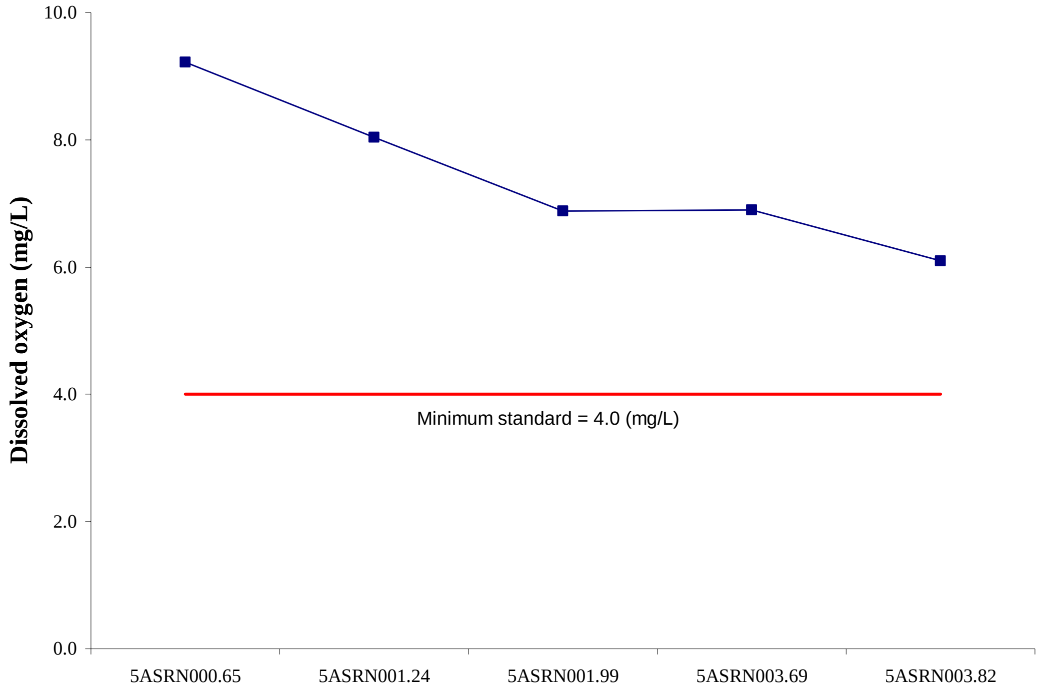

Figure 3.20 Median DO values at VADEQ monitoring stations on Spring Branch.

The dissolved oxygen water quality standard violations are caused by different sources. In the upper portion of Spring Branch, the primary cause is natural swamp-like conditions that are exacerbated by numerous beaver dams. In addition, there are periodic flushes of excess nitrogen compounds from the former Borden Chemical plant site located just above monitoring station 5ASRN003.69. In the lower portion of Spring Branch, natural conditions are also a factor due to beaver dams. In addition, there are excess nutrients being contributed by the Spring Branch Wastewater Treatment Facility and runoff from the Waverly urban area. These excess nutrients contribute to plant growth that leads to severe eutrophication problems seen in Bryant's Pond.

Total phosphorus (TP) concentrations, shown in Figures 3.21 through 3.23, were above the VADEQ assessment screening value of 0.2 mg/L. Thirteen of the 21 TP concentrations at monitoring station 5ASRN001.24 were above the screening level and the maximum concentration was 2.40 mg/L. This monitoring station is just downstream of the Spring Branch Wastewater Treatment Facility discharge. Median concentrations exceeded the screening value in the lower portion of Spring Branch at VADEQ monitoring stations

5ASRN000.65 and 5ASRN001.24 (Figure 3.24). This highlights another difference between the upper and lower portions of Spring Branch.

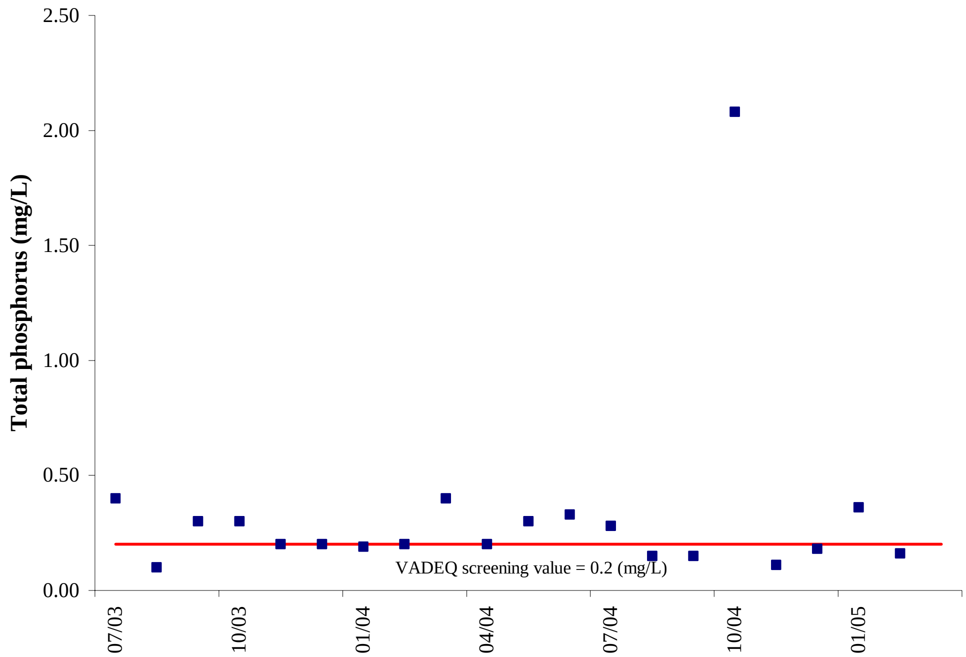

Figure 3.21 TP concentrations at VADEQ monitoring station 5ASRN000.65.

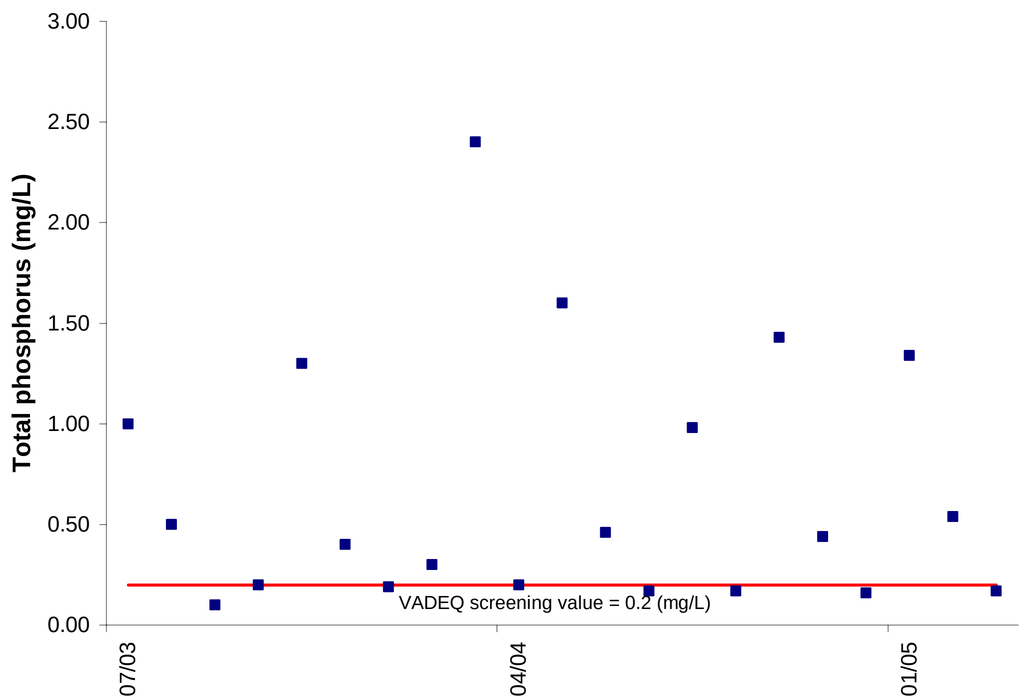

Figure 3.22 TP concentrations at VADEQ monitoring station 5ASRN001.24.

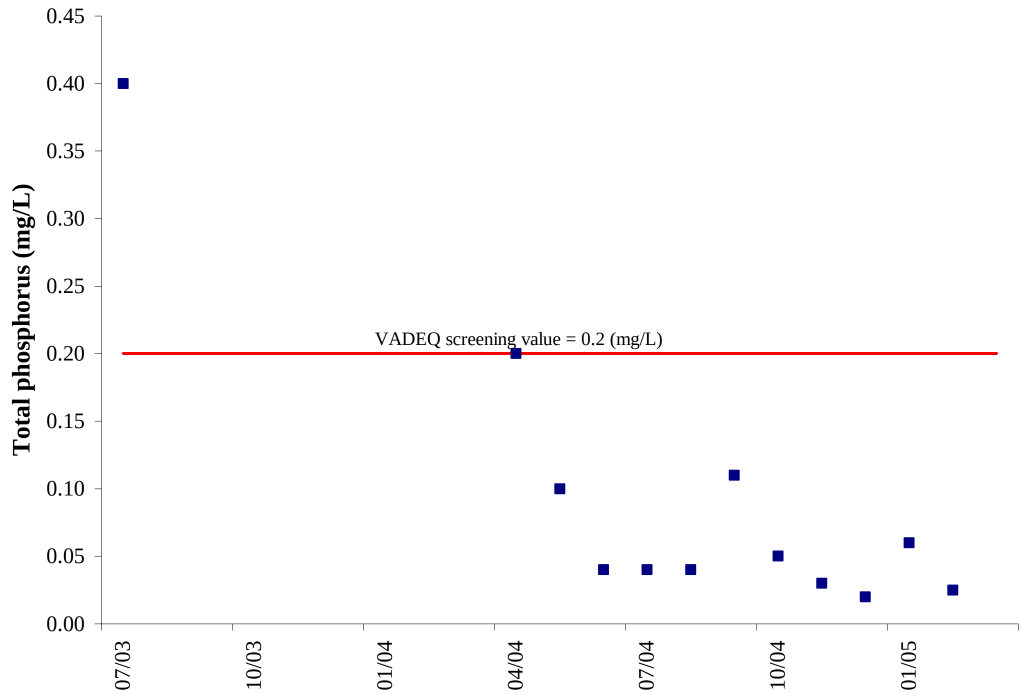

Figure 3.23 TP concentrations at VADEQ monitoring station 5ASRN003.69.

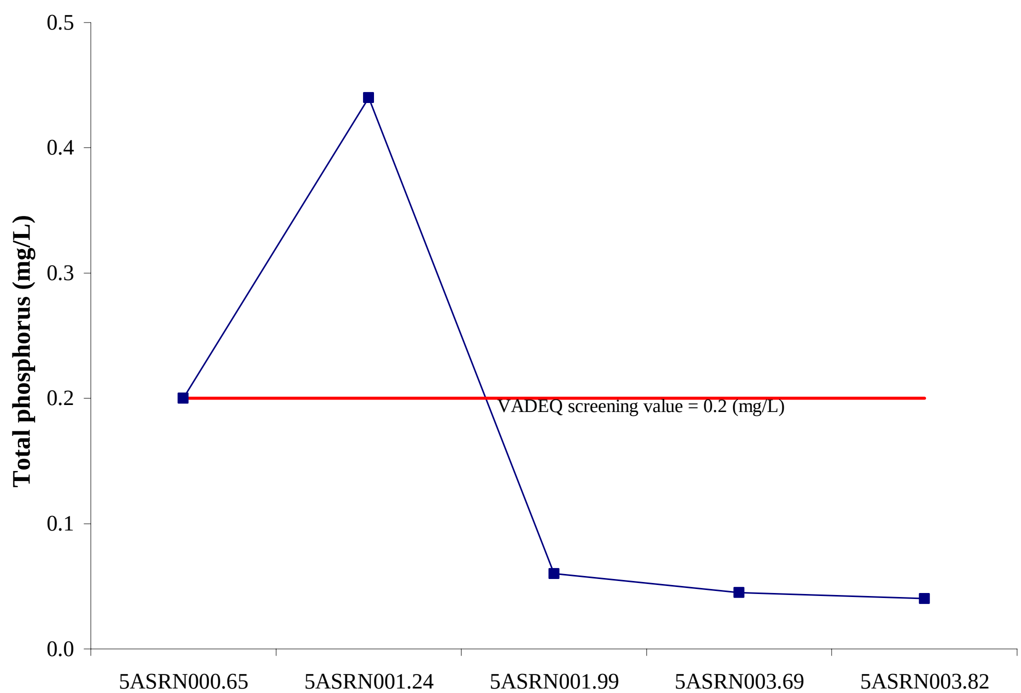

Figure 3.24 Median TP values at VADEQ monitoring stations on Spring Branch.

Nitrite_nitrate-nitrogen ($N0_2$_NO_3-N) concentrations are highest at VADEQ monitoring station 5ASRN001.24 (Figure 3.25). Nitrite-nitrogen (NO_2-N) is typically a minor fraction of the $N0_2$_NO_3-N concentration in flowing streams (<1%); therefore, the majority of the value can be thought of as NO_3-N. While there is no aquatic life water quality standard for NO_3-N at the present time, concentrations in excess of 1.0 mg/L can be considered high compared to streams with swamp-like characteristics. Median concentrations are shown in Figure 3.26.

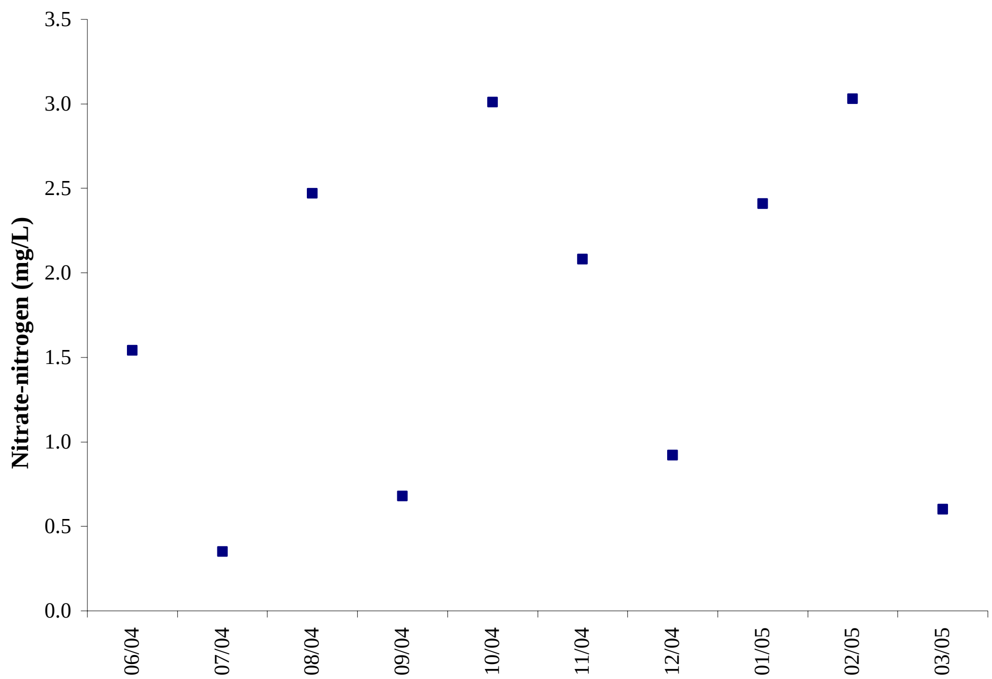

Figure 3.25 NO2_N03-N concentrations at VADEQ monitoring station 5ASRN001.24.

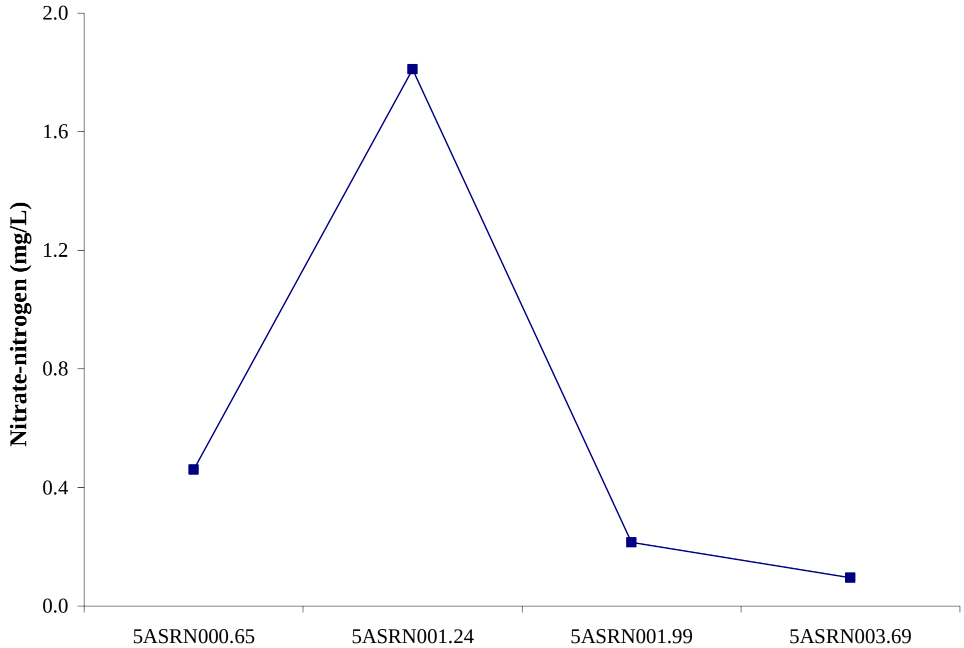

Figure 3.26 Median NO2_N03-N values at VADEQ monitoring stations on Spring Branch.

A more thorough examination of nutrients was done to try and determine the potential for eutrophication from the existing data. The criteria used can be found in *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water* (Mills et al., 1985). The results indicated that TP was the most limiting nutrient at two of the upstream stations (5ASRN001.99 and 5ASRN003.69) and total nitrogen was the most limiting nutrient at the two downstream stations (5ASRN000.65 and 5ASRN001.24). Table 3.6 summarizes the percent of the time that TP and TN concentrations were above the Problem Likely to Exist (PLE) or Severe Problem Possible (SPP) thresholds.

The data in Table 3.6 clearly shows the differences between the upper and lower portions of Spring Branch. If other conditions are right, both TN and TP concentrations are high enough to cause severe eutrophication problems in the lower portion of Spring Branch. Dissolved oxygen levels are not in the normal range and daily pH values below Bryant Pond are occasionally above the 9.0 std units, indicating that eutrophication is a problem. While it is not clear if natural conditions play a major role in this problem, it is obvious that nutrient concentrations are too high and, therefore, nutrients are considered a probable stressor. Because total phosphorus concentrations consistently exceed the VADEQ and USEPA screening value of 0.2 mg/L, and its role in promoting eutrophication is well documented, it will be the stressor that this TMDL focuses on. Figure 3.27 is a picture of Bryant Pond taken in the summer of 2004 that visually indicates the severity of the eutrophication problem.

Table 3.6 Percent of time TP & TN concentrations exceeded the PLE or SPP thresholds.

Station	Parameter	PLE	SPP
5ASRN000.65	TP	89%	6%
5ASRN000.65	TN	93%	7%
5ASRN001.24	TP	94%	17%
5ASRN001.24	TN	100%	6%
5ASRN001.99	TP	0%	0%
5ASRN001.99	TN	47%	0%
5ASRN003.69	TP	18%	0%
5ASRN003.69	TN	56%	0%
5ASRN003.82	TP	17%	0%
5ASRN003.82	TN	33%	0%

Figure 3.27 Bryant Pond on June 24, 2004.

There is extensive scientific literature from multiple states including Virginia that indicate there is a negative correlation between TP and the quality of the benthic community (VADEQ 2004, Miltner and Rankin 1998, and Sheeder and Evans 2004). Furthermore, degradation of the benthic community occurs at TP levels below that observed below the STP (Sheeder and Evans 2004). In the Virginia Probmon biological monitoring program as of 2001, VADEQ collected TP and benthic macroinvertebrate data at 97 randomly selected stream sample sites statewide. Benthic community RBPII metrics were strongly correlated with TP, ortho-phosphorus, total Kjeldahl nitrogen, and ammonia. Mayflies, stoneflies and caddisflies (EPT metric), percent mayflies (PEPH metric), percent scrapers (PSCRAP metric), and the VASCI (the new Virginia Stream Condition Index currently under Academic Advisory Committee review) were negatively related to TP. These insect families, scrapers and the VASCI decline as TP increases. TP negatively impacts the number of families of mayflies, stoneflies, and caddisflies; the percent of mayflies and scrapers in a sample, and an overall community benthic health index. That phosphorus plays a major role in benthic macroinvertebrate impairment has been shown in other states. Ohio EPA (1999) stated that in Ohio higher median TP corresponds to lower biological integrity index values in most ecoregions and stream sizes, and that median background levels of TP are typically much less than 0.10 mg/L statewide in Ohio. Median TP below the Spring Branch STP were 0.43 mg/L. Miltner and Rankin (1998) stated that elevated levels of nitrogen and phosphorus are associated with reduced levels of benthic macroinvertebrate and fish community integrity, and that phosphorus is more strongly associated with levels of stream biological integrity in Iowa. Sheeder and Evans (2004) stated that impaired watersheds in Pennsylvania have median TP levels of 0.15 mg/L, while attaining (healthy) watersheds have median TPs of 0.03 mg/L, thus indicating a strong link between increasing TP and decreasing quality of the benthic community. The same relationship holds for Spring Branch benthic community integrity and total phosphorus during the spring and fall of 2004. This is the period of TMDL development when both macroinvertebrates and nutrients, including TP, were sampled. Median TP at the Warwick Swamp reference station was 0.05 mg/L, and the average benthic RBPII score was 37. At the impaired station on Spring Branch below the STP, the median TP was much higher at 0.43 mg/L, while the average RBPII score was much lower at 23.

Spring Branch TP below the STP contains the highest instream TP that VADEQ has ever found in the Coastal Plain of Virginia, in which Spring Branch is located. With a median of 0.43 mg/L and a mean of 0.71 mg/L during TMDL development, Spring Branch TP below the STP is nearly two times the 100th percentile TP of 0.25 mg/L for waters of the Coastal Plain in the Virginia probabilistic monitoring (Probmon) study of randomly selected stations as of 2001. Spring Branch TP is nearly equal at 0.43 mg/L to the 99th percentile TP of 0.46 mg/L statewide in the Probmon study of 292 randomly selected stations. Further, Spring Branch TP below the STP is also far greater than the Rohm, Omernik, Woods, and Stoddard (2002) median TP of 0.034 mg/L for streams without point source discharges in the Eastern Coastal Plain (Region XIV) of the United States, in which Spring Branch is located. In Rohm et al. less than 10% of the sites had greater than 0.2 mg/L TP, placing the UT Chickahominy River in at least the low 90th percentile of that dataset too. VADEQ data indicates that Spring Branch TP below the STP is greatly in excess of regional background levels. Having the median TP in their receiving stream at twice the 100th percentile of Coastal Plain streams, and at nearly the 99th percentile statewide points to the excessive nature of the Spring Branch STP total phosphorus discharge. See Figure 3.28 for a graphic presentation of the Spring Branch TP below the STP compared to Coastal Plain and statewide TP.

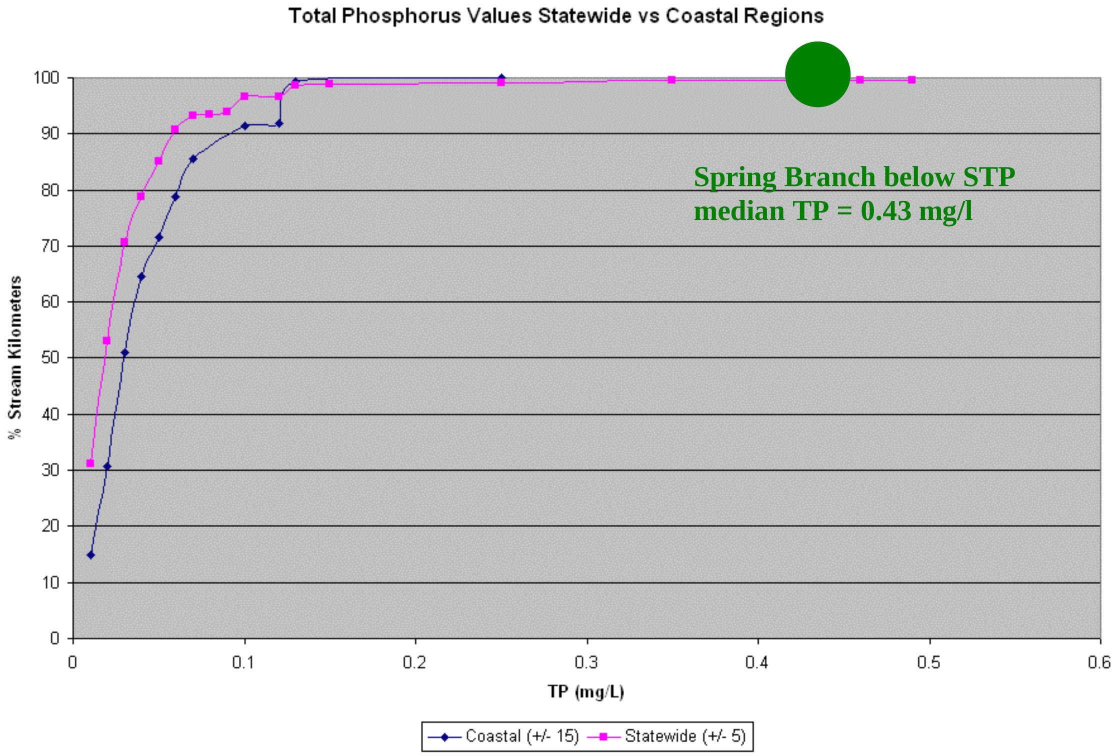

Figure 3.28 Cumulative distribution graph of total phosphorus values statewide and in coastal regions.

VADEQ is considering total phosphorus concentrations in the range of 0.2 mg/L as thresholds for future phosphorus water quality standards. This is well below the 0.43 mg/L median and 0.71 mg/L mean TP level in Spring Branch below the STP outfall. If or when TP water quality standards are enacted by VADEQ and the SWCB, Spring Branch below the STP would again be listed on the 303(d) Impaired waters list for TP, in addition to the current benthic impairment.

The lower portion of Spring Branch is impacted by high nutrients from runoff and the Spring Branch Wastewater Treatment Facility discharge. In order to address the pH and dissolved oxygen water quality standard violations in this part of the stream, a TMDL will be necessary. The benthic TMDL for the lower portion of Spring Branch will focus on reducing the nutrient total phosphorus.

3.5 TMDL Endpoint Selection

The result of the stressor analysis finds that dissolved oxygen minimum water quality standard violations and pH water quality standard violations are the most probable stressors. It is also understood that, due to the geography and unique hydraulic conditions in Spring Branch, natural causes are a factor in the DO and pH water quality standard violations. The upper and lower portions of Spring Branch are impacted by different pollutant sources.

The upper portion of Spring Branch is impacted by natural swamp water conditions. It also receives periodic slugs of nitrogenous waste products that are most likely from the former Borden Chemical glue manufacturing plant site. It appears that urea resin and formaldehyde were disposed of on-site when the plant closed in 2001. VADEQ is working with the current owner of the former Borden Chemical plant site to address sampling and site remediation.

There are currently no comprehensive water quality standards for total phosphorus in the state of Virginia (there is a special total phosphorus water quality standard for the Chickahominy River). Bryant Pond has a long history of hyper-eutrophic conditions and this has resulted in pH values that exceed the maximum standard of 9.0 (std units) downstream of the pond. Therefore, it was logical to select the total phosphorus concentrations in the pond as the endpoint to eliminate the eutrophic conditions and the maximum pH standard violations. In addition, total phosphorus reductions upstream of the pond will lessen the severity of minimum dissolved oxygen concentration violations that occur between the Town of Waverly and the pond. This will improve the benthic macroinvertebrate populations at VADEQ monitoring stations 5ASRN001.24 and 5ASRN000.65.

Carlson's Trophic State Index (TSI) is a measure of the trophic state of a waterbody and can be used to measure the water quality of a lake or pond. The TSI endpoint selected was 60, the threshold at which eutrophic conditions are triggered in lakes and reservoirs. A TSI of 60 corresponds to a total phosphorus concentration of 48.1 µg/L in Bryant Pond. Therefore, 48.1 µg /L total phosphorus was used as the TMDL endpoint in this study.

The model utilized for this TMDL study, EUTROMOD, was originally developed in a study of southeastern lakes and reservoirs by Dr. Kenneth Reckhow at Duke University and later modified by Dr. W. Cully Hession at the Academy of Natural Sciences in Philadelphia, Pennsylvania. The model predicts ambient total phosphorus concentrations in lakes based on phosphorus inputs, hydraulic detention time, and mean depth. EUTROMOD relies on the Carlson Trophic Status Index (TSI) for the total phosphorus endpoint in a lake or reservoir.

4. MODELING PROCEDURES: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Spring Branch watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration, and model application for modeling total phosphorus in Bryant Pond are discussed.

4.1 Modeling Framework Selection

The EUTROMOD water quality model (Reckhow, 1992) was selected as the modeling framework to simulate existing conditions and to perform the total phosphorus TMDL allocations. The EUTROMOD model is a watershed-scale nutrient loading and lake response model. EUTROMOD utilizes the Rational Equation to estimate average annual runoff volumes, and the Universal Soil Loss Equation (USLE) to estimate annual erosion. EUTROMOD then estimates the associated dissolved phosphorus loads and sediment-bound phosphorus loads. Additionally, the model provides the option of including phosphorus loads from precipitation, septic systems, and other permitted and unpermitted discharges.

4.2 Model Setup

Watershed data needed as input to EUTROMOD were generated using GIS spatial coverage, local weather data, literature values, and other data. Watershed boundaries for the impaired stream segment were determined using ESRI "Hydrologic Modeling v1.1" for ArcView 3.1 which extends the spatial analyst to support hydrologic modeling. This was used to delineate watershed and subwatershed boundaries from the National Elevation Dataset (NED) based on flow direction calculations. These data were further refined using USGS 7.5 minute quadrangles through MapTech digitization. To adequately represent the spatial variation in the watershed, the Spring Branch drainage area was divided into six subwatersheds: four above Bryant pond, one draining directly into the pond, and one below the pond (Figure 4.1). Only the five subwatersheds draining to the pond were included in the model.

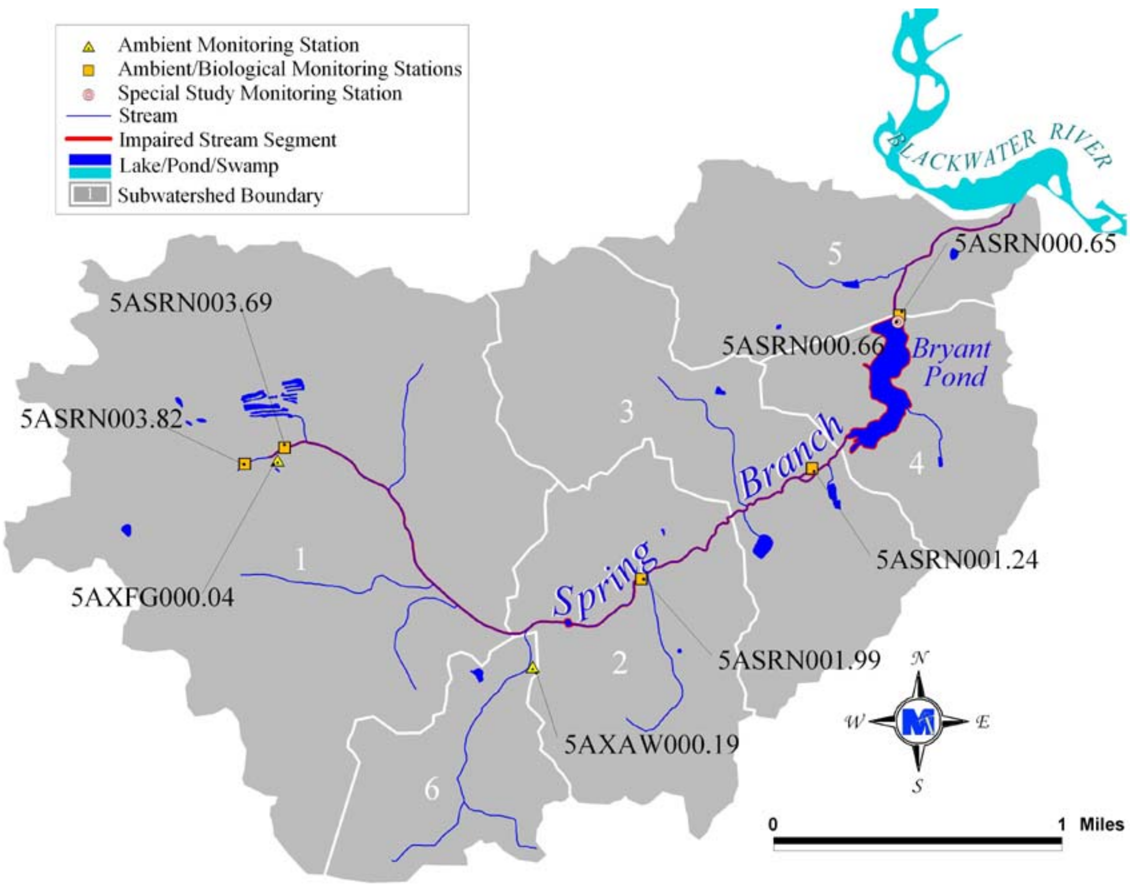

Figure 4.1 Subwatersheds in the Spring Branch watershed.

The EUTROMOD model input parameters used for this project are listed below:

Climatic Parameters

Annual mean precipitation
Precipitation coefficient of variation
Precipitation phosphorus

Watershed Parameters

Runoff coefficients for each land use
USLE Parameters for each land use:

- Rainfall Erosivity
- Soil Erodibility
- Topographic Factor

- Cropping Factor
- Practice Factor

Area per land use

Phosphorus loading factors:

- Dissolved
- Sediment Attached
- Enrichment Ratio

Trapping factors for each subwatershed

Septic system information:

- Number of People
- Phosphorus Load

Point source information:

- Waste Flow
- Phosphorus Concentration

Pond Parameters

Surface area
Mean depth
Annual mean lake evaporation

The annual mean precipitation and precipitation coefficient of variation (cov) used in the model were obtained from annual data collected at the National Climatic Data Center Station #448800 in Wakefield, Virginia. The annual mean precipitation used for input was 77 cm and the precipitation cov was 0.41. The pond parameters were calculated from bathymetry data collected in Bryant Pond at 19 stations on March 18, 2005. The pond area was 0.12 km^2 and the mean depth was 0.86 meters. The annual mean lake evaporation of 1.02 meters was found in Dunne and Leopold (1978).

4.3 Source Representation

Both point and nonpoint sources were represented in the model. In the context of the EUTROMOD model, point sources include all sources that can be modeled as delivering an annual load to the stream, regardless of runoff or erosion variations. In this model, point sources include permitted discharges, sewer line failures, failing septic systems, and precipitation. Nonpoint sources include all sources providing a load through sediment delivery or a phosphorus load in runoff.

4.3.1 Point Sources

Section 2.6 describes the Spring Branch Wastewater Treatment Facility as the only active VPDES permitted discharge in the Spring Branch watershed. The measured discharge of 0.77 MGD and average total phosphorus concentration of 0.82 mg/L from the STP was used to estimate the existing phosphorus load from the permitted discharge. The design flow capacity of 0.90 MGD was used for allocation runs.

During TMDL development, an unpermitted discharge from a sewer line leak was detected and corrected at an unnamed tributary to Spring Branch near monitoring station 5ASRN001.99. In order to account for this load, the measured flow rate (0.072 cfs) and the total phosphorus concentration (0.53 mg/L) to the unnamed tributary from the unpermitted discharge were modeled as a point source to the pond.

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDL for the Spring Branch Study Area. Fifty-two total persons on failing septic systems were calculated using U.S. Census Bureau block demographics. The phosphorus load from failing septic systems was modeled as 1.28 kg/person/year (Metcalf and Eddy, 2003).

Studies have shown that the concentration of phosphorus in precipitation ranges from less than 0.005 mg/L up to 0.5 mg/L, depending on the region and the region's land uses (Novotny and Olem, 1994; Walker, 1998; USGS, 1999; and Walker, 2000). For the phosphorus load from precipitation directly on the pond surface, the average annual phosphorus concentration in rainfall was assumed to be 0.02 mg/L based on the available literature.

4.3.2 Nonpoint Sources

Nonpoint source contributions were identified based on land use categories (Figure 4.2). Table 4.1 lists the total area modeled from each land use type. The EUTROMOD model was used to link pollutants from nonpoint sources with water quality in Bryant Pond. Given the historic pollution problem emanating from the former Borden Chemical site, the drainage area from the site was modeled as a separate land use. The EUTROMOD input parameters used to model the nonpoint sources are shown in Tables 4.2 - 4.4.

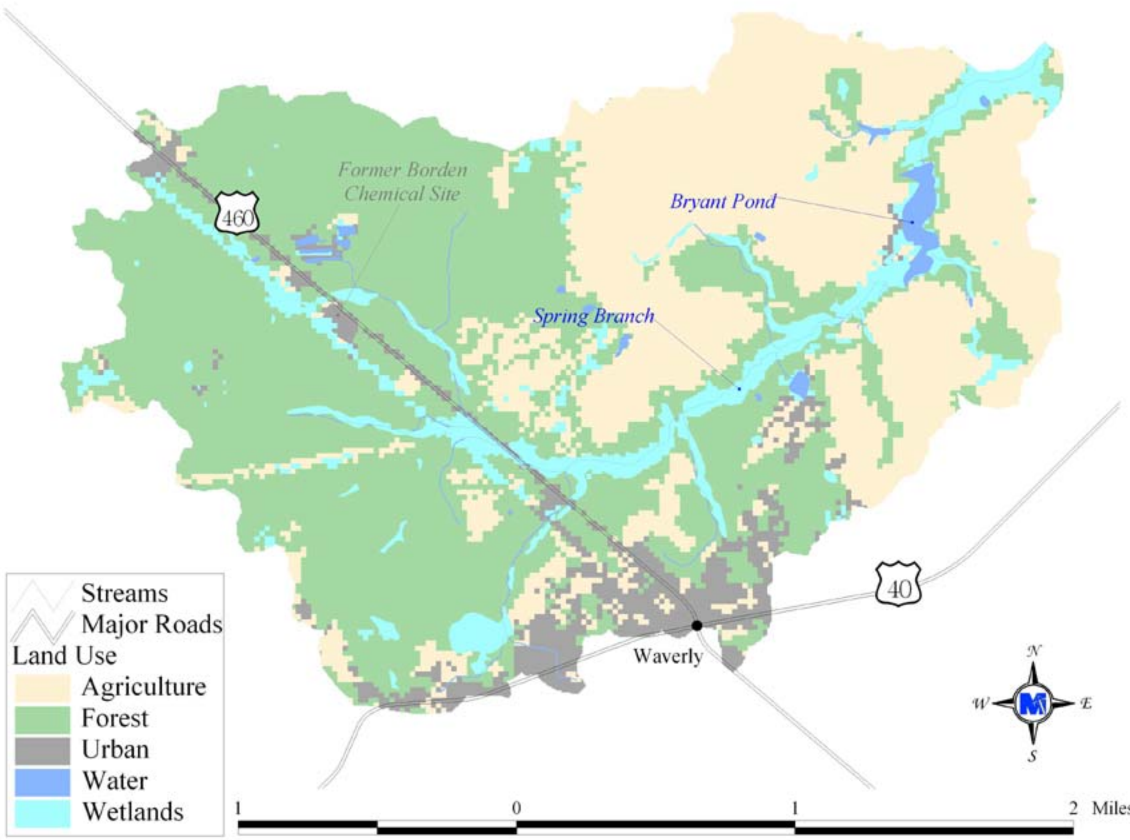

Figure 4.2 Land use categories in the Spring Branch watershed.

Table 4.1 Land uses from Spring Branch watershed draining into Bryant Pond.

Land Use Category	Total Acres Modeled
Former Borden Chemical site	2.8
Cropland	592.7
Forested	1,820.5
Open Space	178.1
Pasture/Hay	376.2
Urban	65.4
Water	46.7
Wetlands	252.0
Total	**3,334.4**

Table 4.2 EUTROMOD/USLE model inputs for the Spring Branch watershed.

Land Use	Runoff Coefficient	Rainfall Erosivity (Mg/ha)	Soil Erodibility	Topographic Factor	Cropping Factor	Practice Factor
Cropland	0.70	560	0.32	0.96	0.400	1.0
Forested	0.16	560	0.16	1.05	0.004	1.0
Pasture/Hay	0.25	560	0.32	0.86	0.060	1.0

Table 4.3 EUTROMOD/Phosphorus loading factors for the Spring Branch watershed.

Land Use	Dissolved Phosphorus (mg/L)	Sediment Attached Phosphorus (mg/kg)	Total Phosphorus (mg/L)
Former Borden Chemical site	--	--	20.00
Cropland	0.160	20.6	--
Forested	0.006	20.6	--
Open Space	--	--	0.10
Pasture/Hay	0.100	20.6	--
Urban	--	--	0.10

-- indicates that the factor is not applicable for this land use

The runoff coefficients for the Rational Formula were estimated from literature values (McCuen, 2004; Schwab et al, 1981; Novotny and Olem, 1994) based on hydrologic soil group, average basin slope, and land use type. The rainfall erosivity, the soil erodibility, and the cropping factors were obtained from Novotny and Olem (1994). The topographic factors were computed using a GIS method of calculating the length of slope and slope of each land use in each subwatershed. The practice factor of 1.0 was chosen since the Spring Branch watershed is nearly level land.

Input for phosphorus loading factors were estimated using research from two studies in the Coastal Plains of Virginia (Mostaghimi et al., 1988; Mostaghimi et al., 1997) for all nonpoint source loads except the former Borden Chemical site. The sediment attached phosphorus content was multiplied by a recommended enrichment ratio of 1.5 (Yagow et al., 2002). The maximum total phosphorus concentration collected from a VADEQ monitoring station in an unnamed tributary to Spring Branch (5AXFG000.04) that drains the former Borden Chemical site was used to calculate the total phosphorus input to the stream from the site.

The EUTROMOD model allows the input of trapping factors to account for sediment trapping within the watershed before the sediment reaches the pond. The trapping factors were used for each subwatershed to account for riparian zones, wetlands, and stream impoundments such as beaver dams.

4.4 Model Calibration

Calibration is performed in order to ensure that the model accurately represents the water quality processes in the watershed. Through calibration, water quality parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as total phosphorus (TP) concentration. Additionally, the limited amount of measured data for use in calibration impedes the calibration process.

The water quality calibration of Spring Branch used the median TP concentration of 0.40 mg/L at in-stream monitoring site 5ASRN001.24 from data collected from 7/22/2003 through 7/5/2005. The trapping factors for the five subwatersheds, the dissolved phosphorus concentrations for the agricultural land uses, and the TP concentrations for the urban land uses were utilized for model adjustment. Changes in the trapping factors change TP loads delivered from sediment, while changes in dissolved phosphorus from agriculture land uses and TP from urban land uses affect TP concentrations in runoff. All of these parameters were initially set at acceptable levels for the watershed conditions and adjusted within reasonable limits until the modeled TP input to the pond equaled the actual median TP concentration. The calibrated trapping factors used in the model were 0.99 for subwatersheds 1 and 6, 0.98 for subwatersheds 2 and 3, and 0.97 for subwatershed 4. This calibrated model also provided a modeled median TP concentration in the pond of 0.22 mg/L, which is close to the actual median concentration in the pond of 0.23 mg/L.

5. ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, nonpoint sources), including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process. The definition is typically denoted by the expression:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For total phosphorus (TP), the TMDL is expressed in terms of loads (*e.g.,* kg/yr) or resulting concentration (*e.g.*, mg/L).

This section describes the development of a TMDL for TP for Spring Branch using the EUTROMOD model. The model was run for existing conditions to develop an annual TP load that represents the TP concentration in the stream.

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of this phosphorus TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of this TMDL are:

- Phosphorus inputs into Bryant Pond can discharge from the pond without being utilized. While this reduction is realized in the system, the TMDL does not account for this and assumes the phosphorus load delivered to the pond remains available for algae production throughout the year.

- The water quality target is conservative. TSI values for a hypereutrophic lake or pond range greater than 70. Establishing a TMDL endpoint of TSI equal to 60 ensures that the pond will not reach a hypereutrophic state.

5.2 Scenario Development

The allocation scenario was modeled using EUTROMOD. Existing conditions were adjusted until the TMDL endpoint was attained. The TMDL developed for Spring Branch was based on a TP concentration of 48.1 μg/L in Bryant Pond. This TP concentration corresponds to the endpoint of TSI equal to 60.

5.2.1.1 Wasteload Allocations

Assuming a design flow of 0.90 million gallons per day and constant concentrations, this load corresponds to an average total phosphorus concentration of slightly less than 0.12 mg/L.

5.2.1.2 Load Allocations

Load allocations are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.*, uncontrolled discharges). The LA for the phosphorus TMDL is 47.88 kg/yr. This load corresponds to an 83.3% reduction in the total phosphorus load from agricultural, urban, and the former Borden Chemical site, and a 100% reduction from failing septic systems and sewer line leaks. Table 5.1 contains the existing and allocated loads for the impairment in Spring Branch, reported as total phosphorus load (kg) per year from both direct and land-based sources. The percent reduction needed to meet this TMDL is given in the final column of these tables. Table 5.2 is known as the TMDL table, which gives the total phosphorus load in Bryant Pond in a given year, which will ensure that the stream will meet existing water quality standards.

Table 5.1 Land-based and direct nonpoint source load reductions in the Spring Branch impairment for final allocation.

Pollutant Source	Total Annual Loading for Existing Run (kg/yr)	Total Annual Loading for Allocation Run (kg/yr)	Percent Reduction
NonPoint Sources			
Agriculture	251.32	41.97	83.3
Former Borden Chemical site	0.89	0.15	83.3
Forest	5.67	5.67	0
Urban	0.56	0.09	83.3
Point Sources			
Failing Septic Systems	66.46	0.000	100
Sewer Line Leak	36.62	0.000	100
Permitted Discharge*	872.40	145.82	83.3

*annual loading based on permitted discharge of 0.90MGD and a concentration less than 0.12 mg/L TP for the allocated condition.

Table 5.2 Annual TP loads (kg/yr) modeled after TMDL allocation in the Spring Branch impairment.

Impairment	WLA (kg/year)	LA (kg/year)	MOS	TMDL (kg/year)
Spring Branch	145.82	47.88	*Implicit*	193.70

6. IMPLEMENTATION

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment on Spring Branch. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary, and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 *Guidance for Water Quality-Based Decisions: The TMDL Process*. The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by the regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Once developed, VADEQ takes the TMDL IP to the SWCB for approval as the plan for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL IP into the appropriate Water Quality Management Plan (WQMP) in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL IPs developed within a river basin. The process for developing an IP has been described in the *Guidance Manual for Total Maximum Daily Load Implementation Plans*, published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of each IP, Virginia works toward restoring its impaired waters and enhances the value of this important resource. Additionally, development of an approved implementation plan improves a locality's chances for obtaining financial and technical assistance during implementation.

6.1 Implementation of the Waste Load Allocation

EPA's approval letters state that "Following the approval of the TMDL, Virginia shall incorporate the TMDL into the appropriate Water Quality Management Plans pursuant to 40 CFR '130.7(d)(2). As you know, all new or revised National Pollutant Discharge Elimination System permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44(d)(1)(vii)(B)."

With respect to the Spring Branch STP permit VA0061310, VADEQ envisions that, after approval by the SWCB and the EPA, the permit would be proposed with a TMDL wasteload allocation of 145.82 kg/yr total phosphorus limit (reissuance due in January 2007). A four-year compliance schedule would be proposed in the permit, as well as annual progress reports to be provided by the Sussex Service Authority (SSA). Voluntary interim effluent monitoring for total phosphorus by SSA would be proposed as well.

The SSA has some options to identify the most cost-effective method to satisfy the permit annual load limit (WLA). For example, the collection system serving the Spring Branch STP is interconnected with another SSA-owned facility, Black Swamp STP. Part of the Spring Branch STP flow could be transferred to Black Swamp. The SSA is also evaluating innovative approaches to reduce phosphorus in its effluent and recently applied for grant funding to explore different options. Infiltration & Inflow (I/I) is a considerable source of flow to the Spring Branch STP. While Spring Branch normally operates at 700,000 gallons per day, I/I is often responsible for flows exceeding the 900,000 gal/day capacity of the facility. Addressing I/I issues will help reduce flow and TP. A combination of these items could be utilized to achieve the WLA.

Another management option that could be considered is relocating the STP outfall to the Blackwater River. The VADEQ anticipates the permit limits to be 10-10-3 (BOD, TSS, TKN) for swampwater conditions. This is only slightly more restrictive than the current permit limits for Spring Branch. With this option, the Spring Branch STP WLA will still be in effect until the new outfall comes on line. Once operating, the TP limits will not be necessary because the Blackwater River is not impaired for benthic macroinvertebrates.

State grant funding may become available through the 2007 fiscal year budget process that could be used to fund several of the management options noted above.

The VADEQ acknowledges that the WLA assigned to the Spring Branch STP approaches what is technologically attainable and will be difficult to achieve. Additionally, the facility is located in a low-income area, placing economic restrictions on feasible alternatives. This, together with the lack of enforcement mechanisms for the stringent nonpoint source controls required by the TMDL, may result in a situation where all available options for the facility have been exhausted but the stream is still not fully supporting the aquatic life use. In this situation, the VADEQ believes that a Use Attainability Analysis (UAA) and/or an economic variance could be considered (see section 6.6).

6.2 Implementation of the Load Allocation

Implementation of BMPs in the watershed will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the efficacy of the TMDL in achieving the water quality standard.

In general, Virginia intends that the required reductions be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, promising management practices include improved nutrient management, use of cover crops, and runoff management systems such as grass swales and buffers. These practices have been shown to be effective in lowering phosphorus concentrations in streams.

Additionally, in both urban and rural areas, reducing the contributions from failing septic systems and sewer line leaks should be a primary implementation focus because of the health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system installation/repair/replacement program and the use of alternative waste treatment systems. In urban areas, reducing the phosphorus loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program.

It should be noted that the TMDL does not address the in-pond sediment-bound phosphorus recycling in the system. Over time, the allocated phosphorus inputs to the pond should control eutrophication. However, if monitoring indicates that the internal loading is a significant component of the phosphorus concentration downstream, in-pond implementation to control the phosphorus recycling should be considered.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL IP. Specific goals for BMP implementation will be established as part of the IP development.

6.3 Follow-up Monitoring

VADEQ will monitor at biological monitoring stations 5ASRN000.65, 5ASRN001.24, 5ASRN001.99, 5ASRN003.69, and 5ASRN000.66 as implementation of corrective actions in the watershed occurs in order to achieve the Stage I implementation goals. Monitoring after corrective actions occur allows the most effective use of monitoring resources in the regional office. VADEQ will use data from these monitoring stations to evaluate improvements in the benthic community, and the effectiveness of TMDL implementation in attainment of the General Standard.

6.4 Linkage to Ongoing Restoration Efforts

VADEQ will continue to follow up with Emanuel Tire Company, the current owner of the former Borden chemical site. Efforts will be aimed at having the responsible party(s) clean up and remediate the site. This process goes beyond the scope of this TMDL. The onsite contamination appears to be localized and there is no solid evidence of a toxicity problem in the headwaters of Spring Branch due to this site.

6.5 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia’s Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture’s Environmental Quality Incentive Program (EQIP), the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. For urban issues, the U.S. Department of Housing and Urban Development administers the Community Development Block Grant Program, and the Virginia Department of Housing and Community Development oversees the Indoor Plumbing Rehabilitation program (VDHCD-IPR).

The *Guidance Manual for Total Maximum Daily Load Implementation Plans* (VADCR and VADEQ, 2003) contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of the Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;
5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or
6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf

The process to address potentially unattainable reductions based on the above is as follows: As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL will be implemented. The expectation would be for the reduction of all controllable sources to the maximum extent practicable using the approaches described in sections 6.1 and 6.2 above. The VADEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the aquatic life use fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

7. PUBLIC PARTICIPATION

The development of the Spring Branch TMDL greatly benefited from public involvement. Table 7.1 details the public participation throughout the project. The first public meeting took place on April 18, 2005 at the Beaverdam Sportsman's Club in Waverly, Virginia with 16 people in attendance. The attendees included six VADEQ representatives, two consultants from MapTech, Inc., one VADCR representative, three local citizens, and representatives from the Sussex County Service Authority, AquaLaw, the Town of Waverly, and Chowan Basin Soil and Water Conservation District. The first technical advisory committee (TAC) meeting was held at the Department of Forestry building in Waverly, Virginia on July 7, 2005. Nine people attended, including five VADEQ representatives, one consultant from MapTech, and stakeholders from the Sussex County Service Authority, the Blackwater/Nottoway Riverkeeper Program and the local community. All agency representatives, county and locality staff, and interested citizens had been invited to the TAC meeting at the first public meeting as well as through a letter or e-mail.

The second TAC meeting was held at the Department of Forestry building in Waverly, Virginia on August 10, 2005. Eleven people attended the meeting including three people representing VADEQ, one VADCR representative, one consultant from MapTech, and representatives from the Sussex County Service Authority, the Blackwater/Nottoway Riverkeeper Program, AquaLaw, the Town of Waverly, and the local community.

The final public meeting was held on August 25, 2005 at the Waverly Town Hall in Waverly, VA. The meeting was publicized in the *Virginia Register* and the *Sussex Surry Dispatch*. The meeting was attended by 15 people, including seven citizens, six government agents and two consultants. The topics discussed included a description of the impairment, finalization of the TMDL process, and the implementation process. There was a 30-day public comment period with 2 written comments received regarding this document.

Table 7.1 Public participation during TMDL development for the Spring Branch watershed.

Date	Location	Attendance[1]	Type	Format
4/18/05	Beaverdam Sportsman's Club Waverly, VA	16	1st Public Meeting	Publicized to gov't agencies and general public
7/7/05	Department of Forestry Building Waverly, VA	9	1st TAC Meeting	Publicized to gov't agencies and citizens who expressed interest at the first public meeting
8/10/05	Department of Forestry Building Waverly, VA	11	2nd TAC Meeting	Publicized to gov't agencies and citizens who expressed interest at the first public meeting
8/25/05	Waverly Town Hall Waverly, VA	15	2nd Public Meeting	Publicized to gov't agencies and general public

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the express purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from VADEQ, VADCR, and local governments. This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to ensure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from USEPA, 1996.

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. (USEPA, 2000)

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric (Biological Metric). The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).
2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). (USEPA, 2000)

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Continuous discharge. A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decomposition*. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge permits (under VPDES)*. A permit issued by the state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry* *can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Effluent guidelines. The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.

Effluent limitation. Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (State Water Control Board, 1997)

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph*. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.

Hydrology*. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use. (USEPA, 2000)

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause. (USEPA, 2000)

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor. (USEPA, 2000)

Infiltration capacity*. The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Leachate. Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.

***Loading, Load, Loading rate**. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

***Load allocation (LA).** The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

***Loading capacity (LC).** The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

***Mass balance.** An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

***Mass loading.** The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

***Mitigation.** Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria. Nonquantitative guidelines that describe the desired water quality goals.

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets*.* *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

***Peak runoff**. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

***Permit.** An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

***Permit Compliance System (PCS).** Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

***Phased/staged approach.** Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

***Point source.** Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

***Pollutant.** Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

***Postaudit.** A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Quartile. The 25th, 50th, and 75th percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol (RBP). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Re-mining. Extracting resources from land previously mined. This method is often used to reclaim abandoned mine areas.

Reserve capacity. *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient*. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

Simulation. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor. (USEPA, 2000)

Spatial segmentation*. A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (*e.g.* 200 cfu/100 ml geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (*i.e.* a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff*. Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. (USEPA, 2000)

Surface area*. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water*. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards*. Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (*e.g.,* 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment*.* *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality*.* *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit*.* *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water quality standard. Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

WQIA. Water Quality Improvement Act.

APPENDIX A

ORGANIC COMPOUNDS SAMPLED by VADEQ at 5AXFG000.04

Date	Parameter_Name	Value	Comment_Description
8/31/04	DICLBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	CARBNTET TOTUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	BROMOFRMWHL-WTR UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	CLDIBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	CHLRFORM TOTUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	ACENAPHTHYLENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	ACENAPHTHENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	ANTHRACENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	BENZBFLUORANT TOTAL UG/L	2	Not detected. Value is limit of detection.
8/31/04	BENZO(K)FLUORANTTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	BENZO(A)PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	BIS2CHLOROETHYLETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	BIS2CHLOROETHOXYTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	BIS2CHLOROISOPROTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	NBB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
8/31/04	CHLOROBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	CHLOROETHANE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	CHRYSENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	DIETHYLPHTHALATETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	DIMETHYLPHTHALATTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	ETHYLBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	FLUORANTHENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	FLUORENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	HEXACHLOROCYCLOPTOTWUG/L	6	Not detected. Value is limit of detection.
8/31/04	HEXACHLOROETHANETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	INDENO(123CD)PYRTOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	ISPHRONE TOTUG/L	2	Not detected. Value is limit of detection.
8/31/04	METHYLBROMIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	METHYLCHLORIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	METHYLENECHLORIDTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	NITROSODIPROPYLATOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	NITROSODIPHENYLATOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	NITROSODIMETHYLATOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	NITROBENZENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	PARACHLOROMETACRTOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	PHENANTHRENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	TETRACHLOROETHYLTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	TRICHLOROFLUOROMTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	11DICHLOROETHANETOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	11DICHLOROETHYLETOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	111TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
8/31/04	112TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1122TETRACHLOROETOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	BENZO(GHI)PERYLETOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	BENZO(A)ANTHRACETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	12DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	12DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	12DICHLOROPROPANTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	12DICHLOROETHENETOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	124TRICHLOROBENZTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	124TRICHLOROBENZTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	DIBENZ(AH)ANTHRATOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	13DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	13DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	14DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	14DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	2CHLOROETHYLVINYTOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	2CHLORONAPHTHALETOTWUG/L	8	Not detected. Value is limit of detection.
8/31/04	2CHLOROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	2NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	DINOCTPH TOTUG/L	2	Not detected. Value is limit of detection.
8/31/04	24DICHLOROPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	24DIMETHYLPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	24DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	24DINITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	246TRICHLOROPHENTOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	26DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	4BROMOPHENYLPHENTOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	4CHLOROPHENYLPHETOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	4NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
8/31/04	46DINITROORTHOCRTOTWUG/L	8	Not detected. Value is limit of detection.
8/31/04	PHENOL TOT UG/L	4	Not detected. Value is limit of detection.
8/31/04	NAPTHALENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
8/31/04	NAPTHALENE TOTWUG/L	2	Not detected. Value is limit of detection.
8/31/04	T1,3-DCPTOT WAT UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	C1,3-DCP TOT WAT UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	PCP TOT UG/L	12	Not detected. Value is limit of detection.
8/31/04	B2ETHHXLPHTHALATTOT UG/L	3.6	Confirmed by Mass Spec.
8/31/04	DNB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
8/31/04	VINYLCHLORIDE TOT UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	TRICHLORETHYLENETOT UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	HCB TOT UG/L	2	Not detected. Value is limit of detection.
8/31/04	C-1,2DCE TOTAL UG/L	0.5	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
8/31/04	STYRENE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1,1DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	2,2DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1,3DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1,2,4TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	IPROPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	N-PRPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1,3,5TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	N-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	SEC-BUTB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	T-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1M4ISOPB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1112TCLE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	123TCLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	1,2DBRET TOTAL UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	XYLENE TOT UG/L	1	Not detected. Value is limit of detection.
8/31/04	BROMODICHLOROPROPANE, TOTAL, WATER, UG/L	0.5	Not detected. Value is limit of detection.
8/31/04	P-CHLOROTOLUENE, WHOLE WATER, UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	DICLBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	CARBNTET TOTUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	BROMOFRMWHL-WTR UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	CLDIBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	CHLRFORM TOTUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	ACENAPHTHYLENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	ACENAPHTHENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	ACNAPTHESEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	ANTHRACENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	ANTHRACESEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	BENZBFLUORANT TOTAL UG/L	2	Not detected. Value is limit of detection.
2/9/05	BENZBFLUORANTMUDDRYUG/KG	18.3	Not detected. Value is limit of detection.
2/9/05	BENZO(K)FLUORANTTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	BENZKFLUSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	BENZO(A)PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	DELTABHC TOTUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	BIS2CHLOROETHYLETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	BIS2CHLOROETHOXYTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	BIS2CHLOROISOPROTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	NBB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
2/9/05	CHLOROBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	CHLOROETHANE TOTWUG/L	0.5	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/9/05	CHRYSENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	CHRYSENESEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	DIETHYLPHTHALATETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	DETHPHTHSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	DIMETHYLPHTHALATTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	DMETPHTHSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	ENDSULSF TOTUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	BENDOSULSEDUG/KG DRY WGT	3.7	Not detected. Value is limit of detection.
2/9/05	A-ENDO SULFAN TOTWUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	ETHYLBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	FLUORANTHENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	FLANTENESEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	FLUORENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	FLUORENESEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	HEXACHLOROCYCLOPTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	HEXCLCPDSEDUG/KG DRY WGT	3.7	Not detected. Value is limit of detection.
2/9/05	HEXACHLOROETHANETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	INDENO(123CD)PYRTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	I123CDPRSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	ISPHRONE TOTUG/L	2	Not detected. Value is limit of detection.
2/9/05	METHYLBROMIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	METHYLCHLORIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	METHYLENECHLORIDTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	NITROSODIPROPYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	NITROSODIPHENYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	NITROSODIMETHYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	NAPTHALESEDUG/KG DRY WGT	11	Present but not quantified.
2/9/05	NITROBENZENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	PARACHLOROMETACRTOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	PHENANTHRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	PYRENE SEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	TETRACHLOROETHYLTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	TRICHLOROFLUOROMTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	11DICHLOROETHANETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	11DICHLOROETHYLETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	111TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	112TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1122TETRACHLOROETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	BENZO(GHI)PERYLETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	BENZO(A)ANTHRACETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	12DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/9/05	12DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	12DICHLOROPROPANTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	12DICHLOROETHENETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	124TRICHLOROBENZTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	124TRICHLOROBENZTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	DIBENZ(AH)ANTHRATOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	DBAHANTHSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	13DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	13DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	14DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	14DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	2CHLOROETHYLVINYTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	2CHLORONAPHTHALETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	2CHLOROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	2NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	DINOCTPH TOTUG/L	2	Not detected. Value is limit of detection.
2/9/05	DINOCTPHSEDUG/KG DRY WGT	18.3	Not detected. Value is limit of detection.
2/9/05	24DICHLOROPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	24DIMETHYLPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	24DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	24DINITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	246TRICHLOROPHENTOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	26DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	4BROMOPHENYLPHENTOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	4CHLOROPHENYLPHETOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	4NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	46DINITROORTHOCRTOTWUG/L	4	Not detected. Value is limit of detection.
2/9/05	PHENOL TOT UG/L	4	Not detected. Value is limit of detection.
2/9/05	NAPTHALENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/9/05	NAPTHALENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/9/05	T1,3-DCPTOT WAT UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	C1,3-DCP TOT WAT UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	PCP TOT UG/L	4	Not detected. Value is limit of detection.
2/9/05	PCP SEDUG/KG DRY WGT	6	Not detected. Value is limit of detection.
2/9/05	B2ETHHXLPHTHALATTOT UG/L	2	Not detected. Value is limit of detection.
2/9/05	B2E PHTHMUD-DRY UG/KG	135	Present but not quantified.
2/9/05	DNB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
2/9/05	DNB PHTHMUD-DRY UG/KG	18.3	Not detected. Value is limit of detection.
2/9/05	VINYLCHLORIDE TOT UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	TRICHLORETHYLENETOT UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	P,P'DDT TOT UG/L	3.7	Not detected. Value is limit of detection.
2/9/05	P,P'DDD TOT UG/L	3.7	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/9/05	P,P'DDE TOT UG/L	3.7	Not detected. Value is limit of detection.
2/9/05	ALDRIN SEDUG/KG DRY WGT	3.7	Not detected. Value is limit of detection.
2/9/05	ALPHABHC TOTUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	BETA BHC TOTUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	GAMMABHCLINDANE TOT.UG/L	3.7	Not detected. Value is limit of detection.
2/9/05	DIELDRINSEDUG/KG DRY WGT	3.7	Not detected. Value is limit of detection.
2/9/05	ENDRIN TOT UG/L	3.7	Not detected. Value is limit of detection.
2/9/05	ETHION MUD UG/KG	3.7	Not detected. Value is limit of detection.
2/9/05	HEPTCHLRSEDUG/KG DRY WGT	3.7	Not detected. Value is limit of detection.
2/9/05	HPCHLREP TOTUG/L	3.7	Not detected. Value is limit of detection.
2/9/05	MALATHN MUD UG/KG	3.7	Not detected. Value is limit of detection.
2/9/05	HCB TOT UG/L	2	Not detected. Value is limit of detection.
2/9/05	SILVEX MUD UG/KG	6	Not detected. Value is limit of detection.
2/9/05	TRITHION MUD UG/KG	3.7	Not detected. Value is limit of detection.
2/9/05	C-1,2DCE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	STYRENE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1,1DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	2,2DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1,3DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1,2,4TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	IPROPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	N-PRPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1,3,5TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	N-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	SEC-BUTB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	T-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1M4ISOPB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1112TCLE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	123TCLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	1,2DBRET TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	BTLBNZYLPHTHALATSEDUG/KG	18.3	Not detected. Value is limit of detection.
2/9/05	BZO(GHI)PERYLENESEDUG/KG	18.3	Not detected. Value is limit of detection.
2/9/05	2-METNAPDRY WGT SEDUG/KG	14.4	
2/9/05	XYLENE TOT UG/L	1	Not detected. Value is limit of detection.
2/9/05	ASPON, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	BROMODICHLOROPROPANE, TOTAL, WATER, UG/L	0.5	Not detected. Value is limit of detection.
2/9/05	CROTOXYPHOS, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	FENITROTHION, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	3,5-DCBA, Sediment, dry wt. ppb (ug/kg)	6	Not detected. Value is limit of detection.
2/9/05	LEPTOPHOS, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/9/05	METASYSTOX, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 1, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 101, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 110, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 138, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 141 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 151 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 153 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 170 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 18, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 180 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 183 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 187 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 206 Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 44, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 52, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	PCB 66, Sediment, dry wt. ppb (ug/kg)	3.7	Not detected. Value is limit of detection.
2/9/05	P-CHLOROTOLUENE, WHOLE WATER, UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	DICLBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	CARBNTET TOTUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	BROMOFRMWHL-WTR UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	CLDIBRMT TOTUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	CHLRFORM TOTUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	ACENAPHTHYLENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	ACENAPHTHENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	ANTHRACENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BENZBFLUORANT TOTAL UG/L	2	Not detected. Value is limit of detection.
2/28/05	BENZO(K)FLUORANTTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BENZO(A)PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BIS2CHLOROETHYLETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BIS2CHLOROETHOXYTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BIS2CHLOROISOPROTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	NBB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
2/28/05	CHLOROBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	CHLOROETHANE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	CHRYSENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	DIETHYLPHTHALATETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	DIMETHYLPHTHALATTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	ETHYLBENZENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	FLUORANTHENE TOTWUG/L	2	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/28/05	FLUORENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	HEXACHLOROCYCLOPTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	HEXACHLOROETHANETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	INDENO(123CD)PYRTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	ISPHRONE TOTUG/L	2	Not detected. Value is limit of detection.
2/28/05	METHYLBROMIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	METHYLCHLORIDE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	METHYLENECHLORIDTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	NITROSODIPROPYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	NITROSODIPHENYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	NITROSODIMETHYLATOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	NITROBENZENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	PARACHLOROMETACRTOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	PHENANTHRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	PYRENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	TETRACHLOROETHYLTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	TRICHLOROFLUOROMTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	11DICHLOROETHANETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	11DICHLOROETHYLETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	111TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	112TRICHLOROETHATOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1122TETRACHLOROETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	BENZO(GHI)PERYLETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	BENZO(A)ANTHRACETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	12DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	12DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	12DICHLOROPROPANTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	12DICHLOROETHENETOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	124TRICHLOROBENZTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	124TRICHLOROBENZTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	DIBENZ(AH)ANTHRATOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	13DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	13DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	14DICHLOROBENZENTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	14DICHLOROBENZENTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	2CHLOROETHYLVINYTOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	2CHLORONAPHTHALETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	2CHLOROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	2NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	DINOCTPH TOTUG/L	2	Not detected. Value is limit of detection.
2/28/05	24DICHLOROPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	24DIMETHYLPHENOLTOTWUG/L	4	Not detected. Value is limit of detection.

Date	Parameter_Name	Value	Comment_Description
2/28/05	24DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	24DINITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	246TRICHLOROPHENTOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	26DINITROTOLUENETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	4BROMOPHENYLPHENTOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	4CHLOROPHENYLPHETOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	4NITROPHENOL TOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	46DINITROORTHOCRTOTWUG/L	4	Not detected. Value is limit of detection.
2/28/05	PHENOL TOT UG/L	4	Not detected. Value is limit of detection.
2/28/05	NAPTHALENE TOTWUG/L	0.5	Not detected. Value is limit of detection.
2/28/05	NAPTHALENE TOTWUG/L	2	Not detected. Value is limit of detection.
2/28/05	T1,3-DCPTOT WAT UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	C1,3-DCP TOT WAT UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	PCP TOT UG/L	4	Not detected. Value is limit of detection.
2/28/05	B2ETHHXLPHTHALATTOT UG/L	2	Not detected. Value is limit of detection.
2/28/05	DNB PHTH TOTAL UG/L	2	Not detected. Value is limit of detection.
2/28/05	VINYLCHLORIDE TOT UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	TRICHLORETHYLENETOT UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	HCB TOT UG/L	2	Not detected. Value is limit of detection.
2/28/05	C-1,2DCE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	STYRENE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1,1DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	2,2DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1,3DCLPR TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1,2,4TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	IPROPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	N-PRPBNZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1,3,5TMB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	N-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	SEC-BUTB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	T-BUTLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1M4ISOPB TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1112TCLE TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	123TCLBZ TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	1,2DBRET TOTAL UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	XYLENE TOT UG/L	1	Not detected. Value is limit of detection.
2/28/05	BROMODICHLOROPROPANE, TOTAL, WATER, UG/L	0.5	Not detected. Value is limit of detection.
2/28/05	P-CHLOROTOLUENE, WHOLE WATER, UG/L	0.5	Not detected. Value is limit of detection.

APPENDIX B

IN-STREAM WATER CHEMISTRY DATA

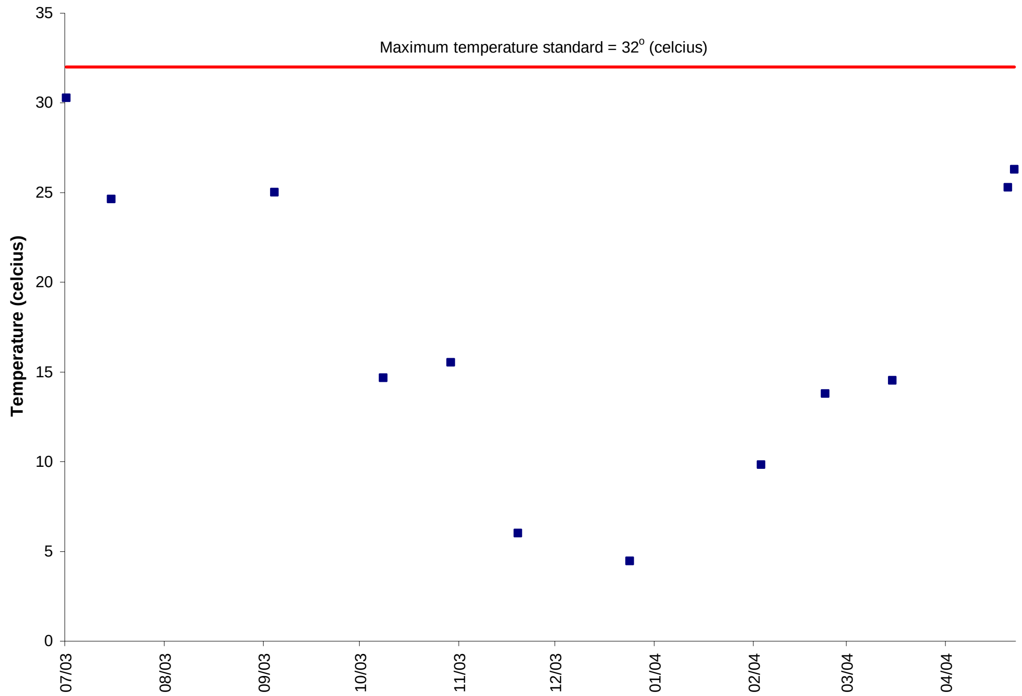

Figure B.1 Temperature at monitoring station 5ASRN000.65.

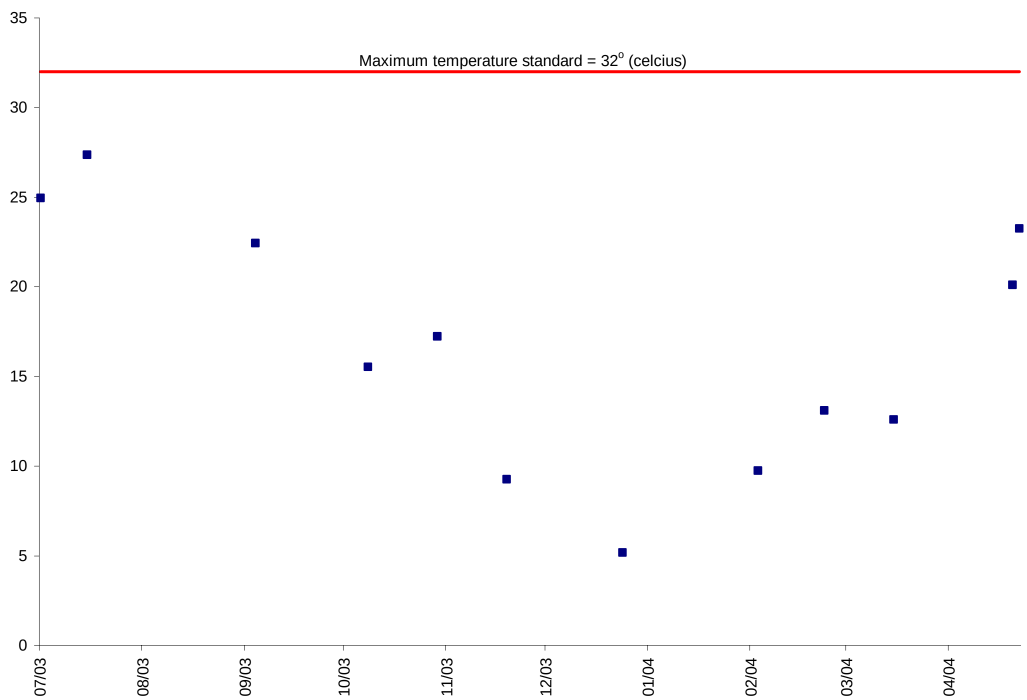

Figure B.2 Temperature at monitoring station 5ASRN001.24.

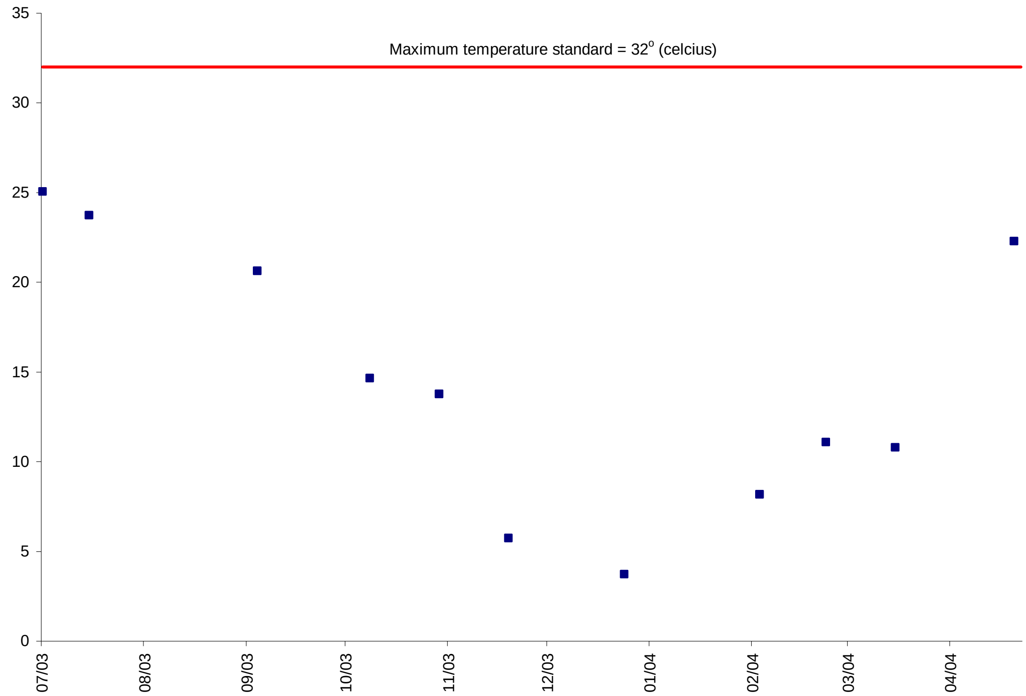

Figure B.3 Temperature at monitoring station 5ASRN001.99.

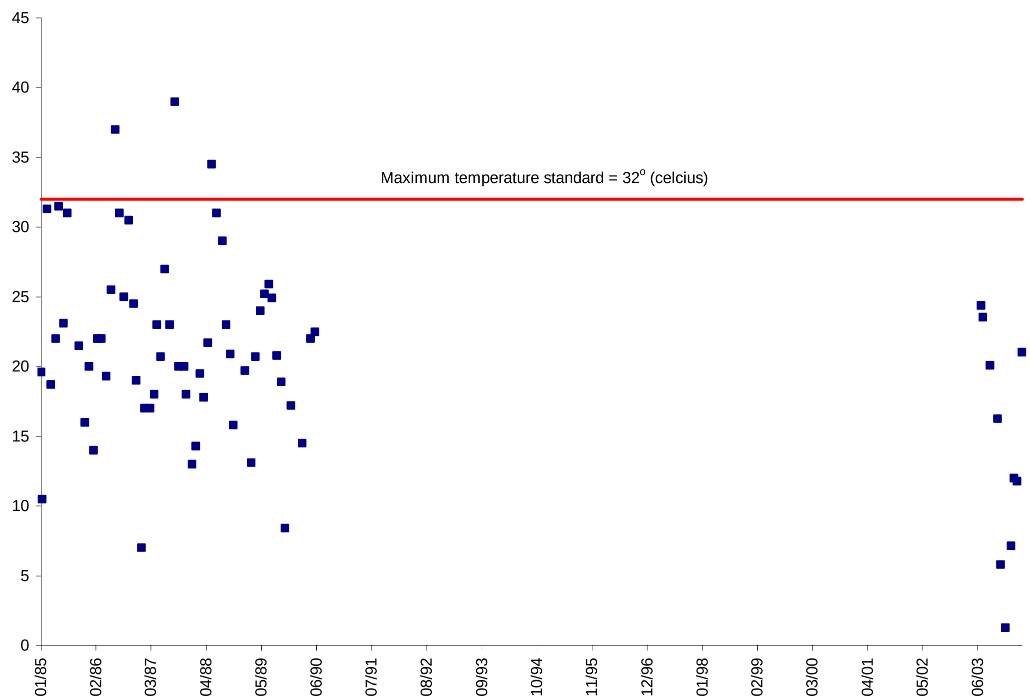

Figure B.4 Temperature at monitoring station 5ASRN003.69.

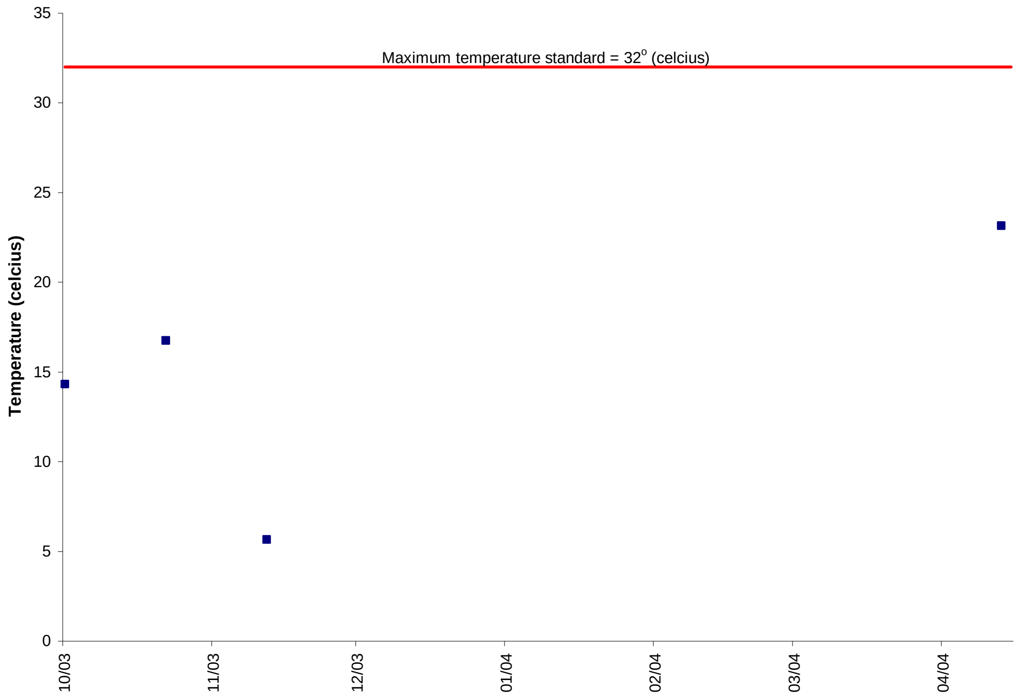

Figure B.5 Temperature at monitoring station 5ASRN003.82.

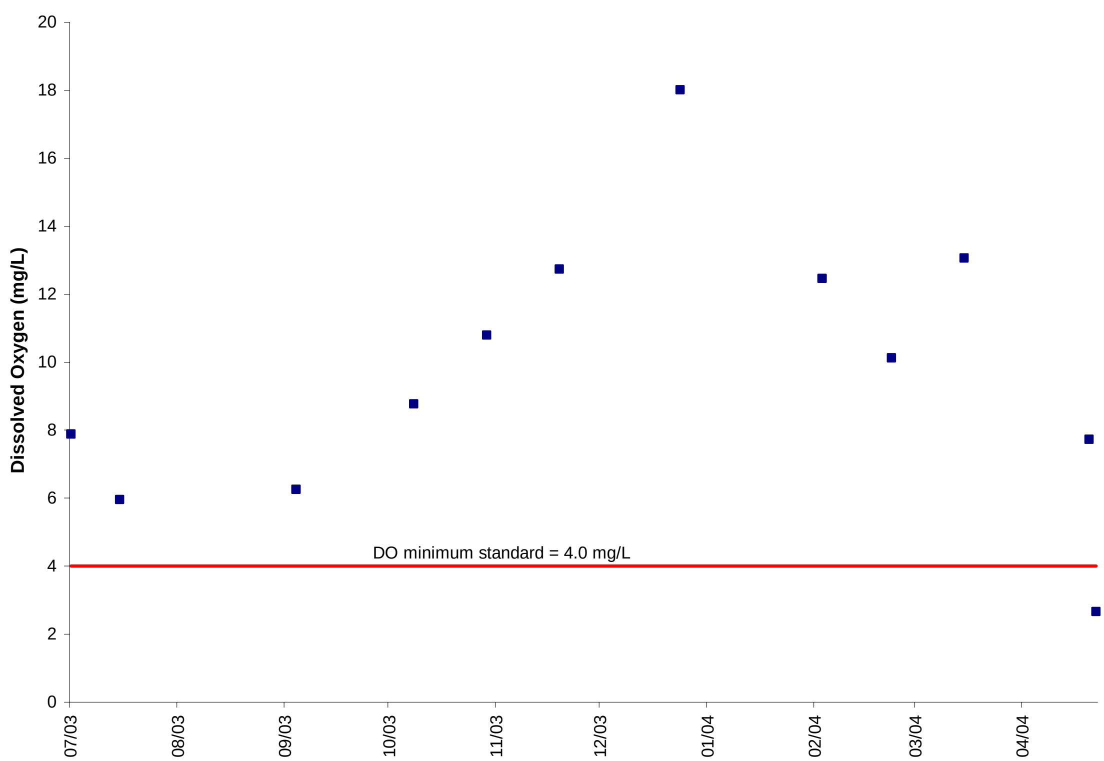

Figure B.6 Dissolved oxygen at monitoring station 5ASRN000.65.

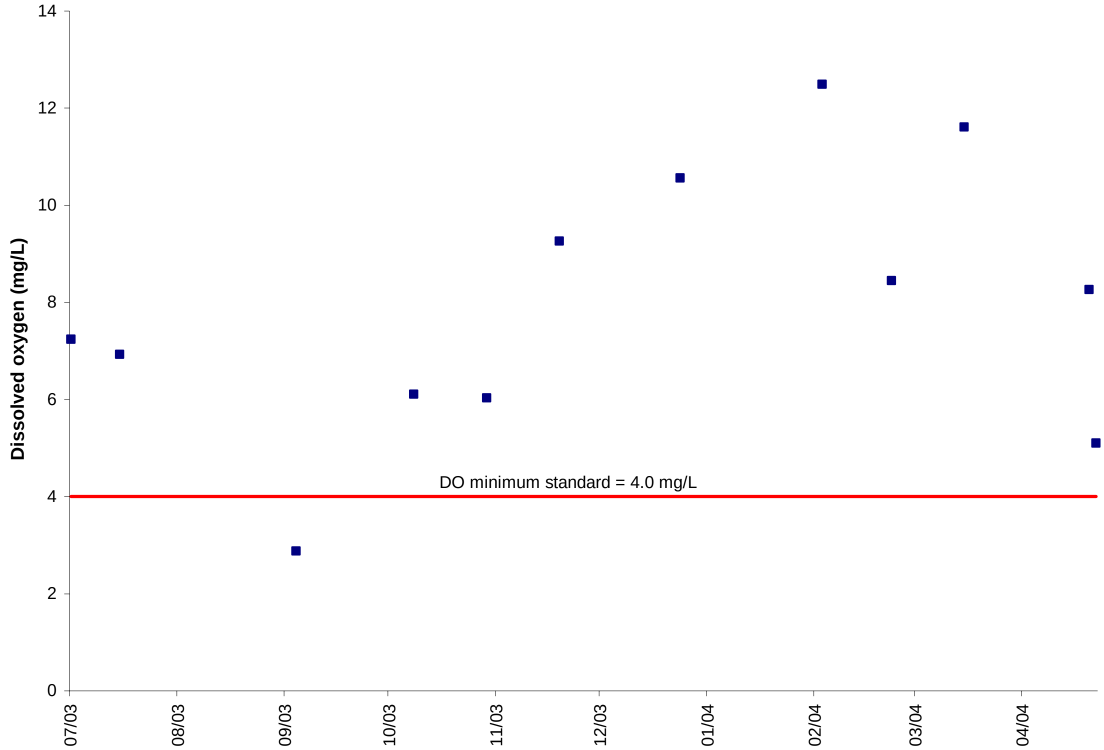

Figure B.7 Dissolved oxygen at monitoring station 5ASRN001.24.

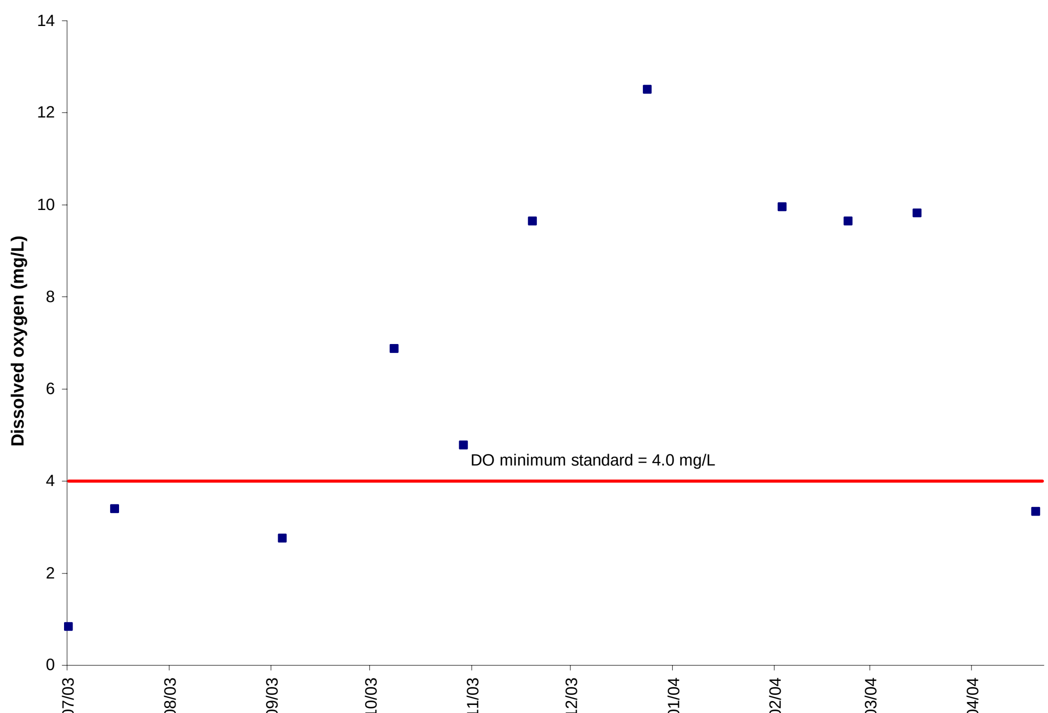

Figure B.8 Dissolved oxygen at monitoring station 5ASRN001.99.

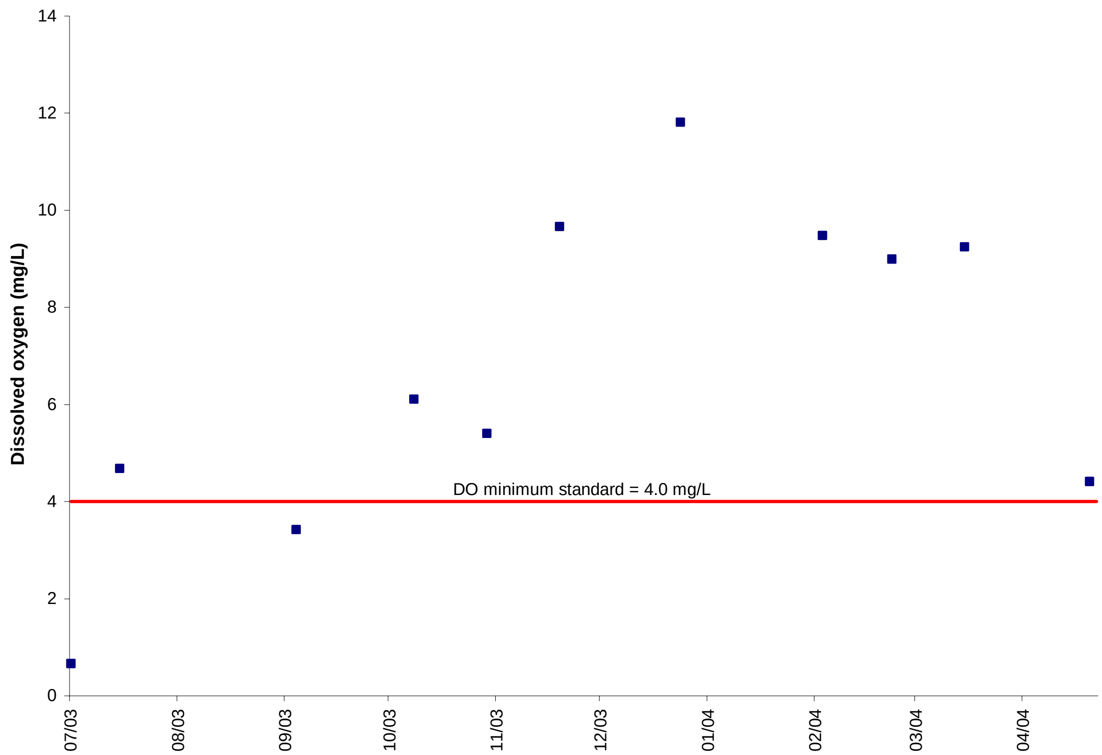

Figure B.9 Dissolved oxygen at monitoring station 5ASRN003.69.

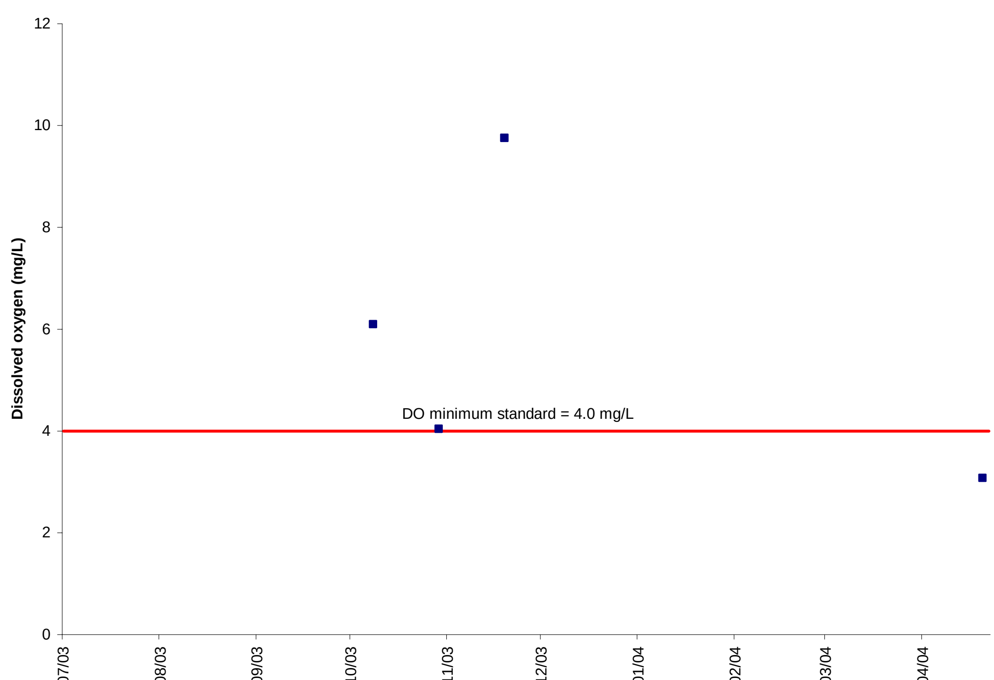

Figure B.10 Dissolved oxygen at monitoring station 5ASRN003.82.

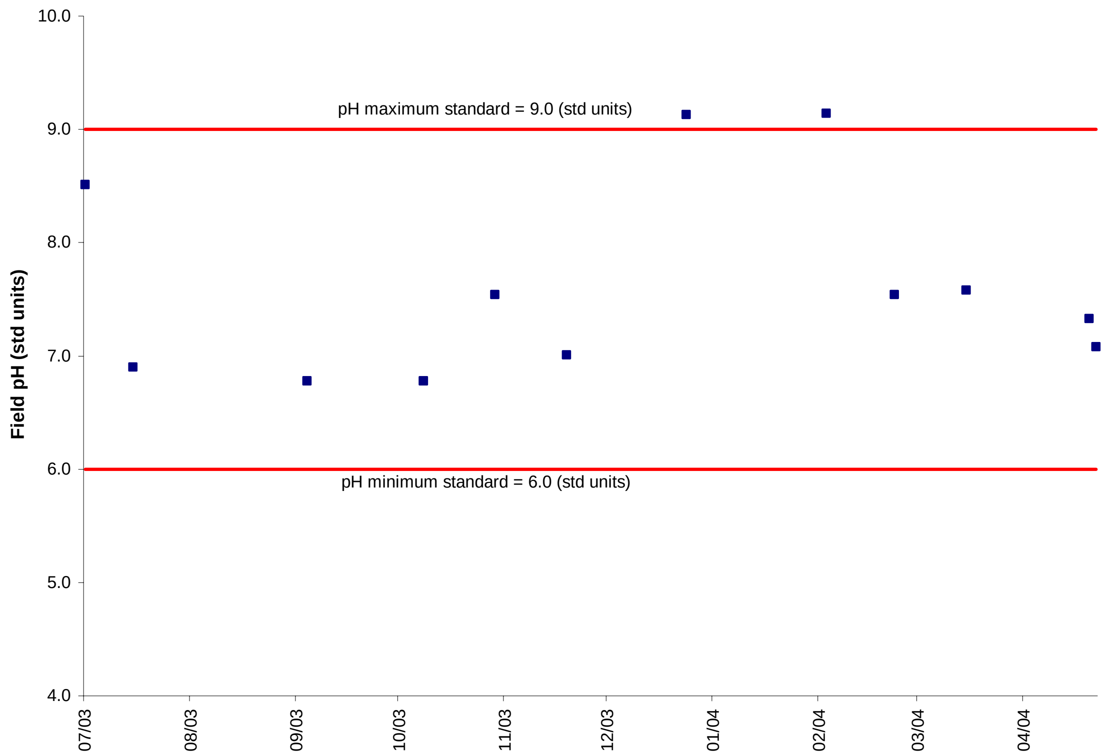

Figure B.11 Field pH at monitoring station 5ASRN000.65.

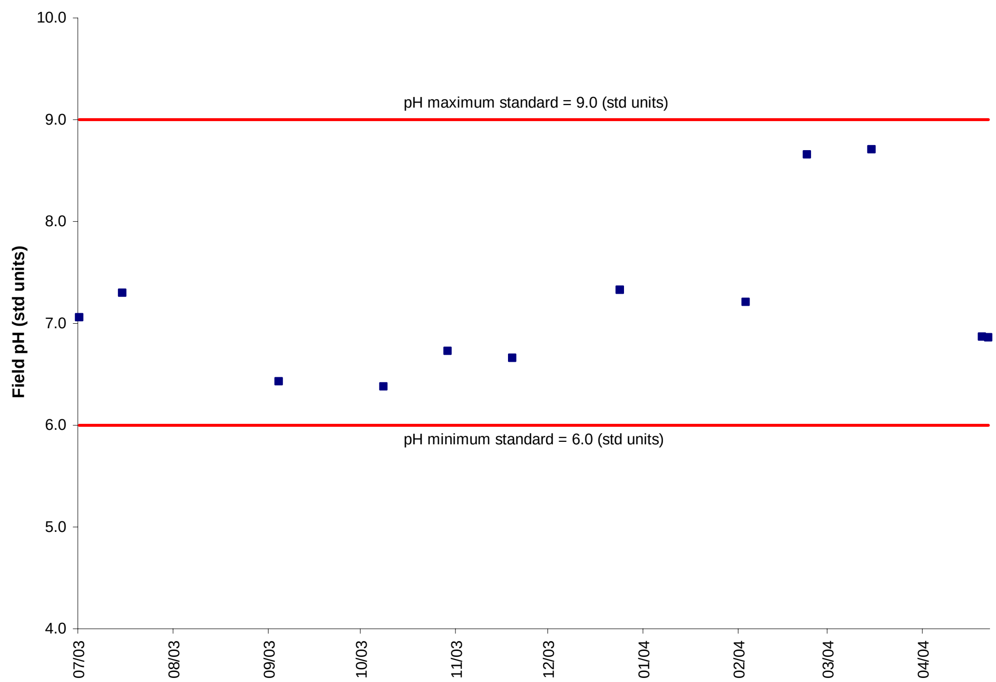

Figure B.12 Field pH at monitoring station 5ASRN001.24.

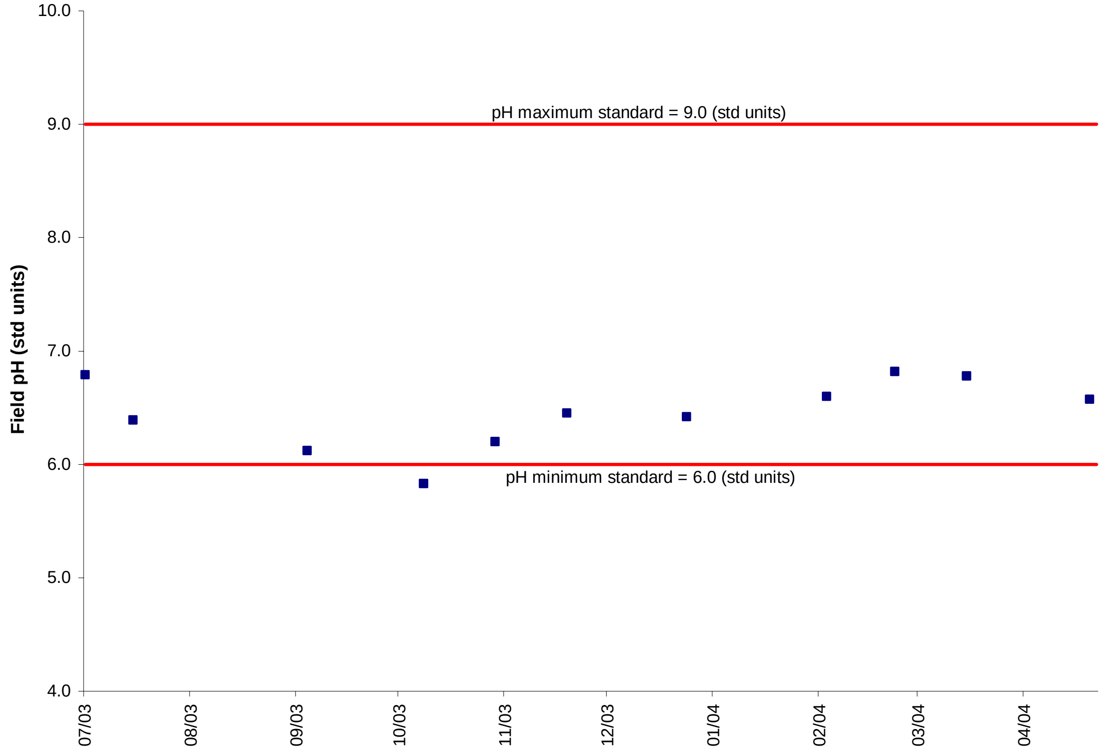

Figure B.13 Field pH at monitoring station 5ASRN001.99.

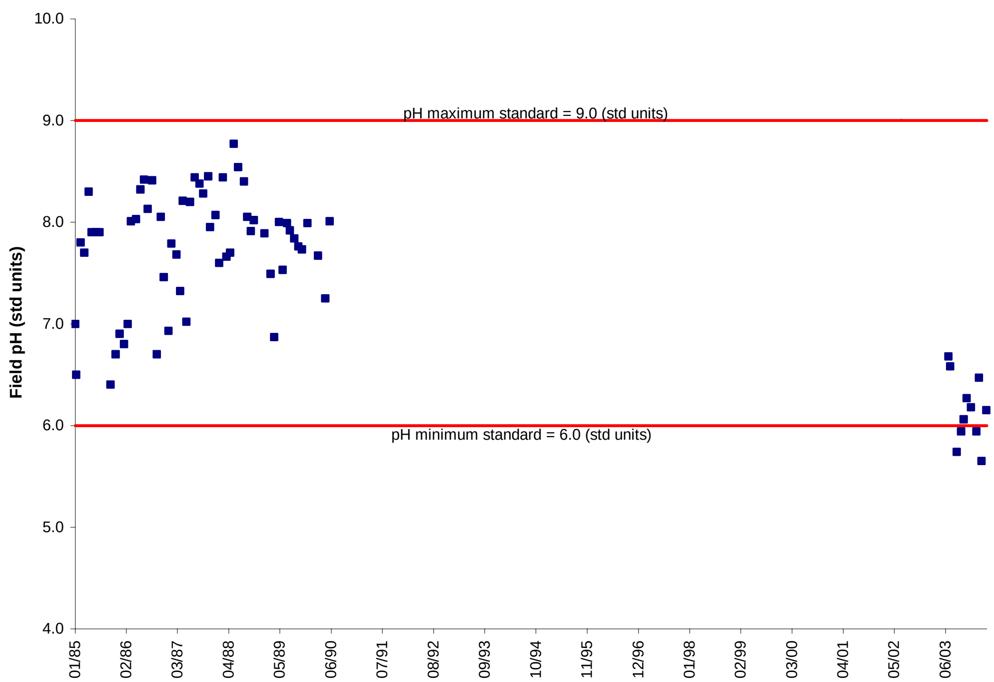

Figure B.14 Field pH at monitoring station 5ASRN003.69.

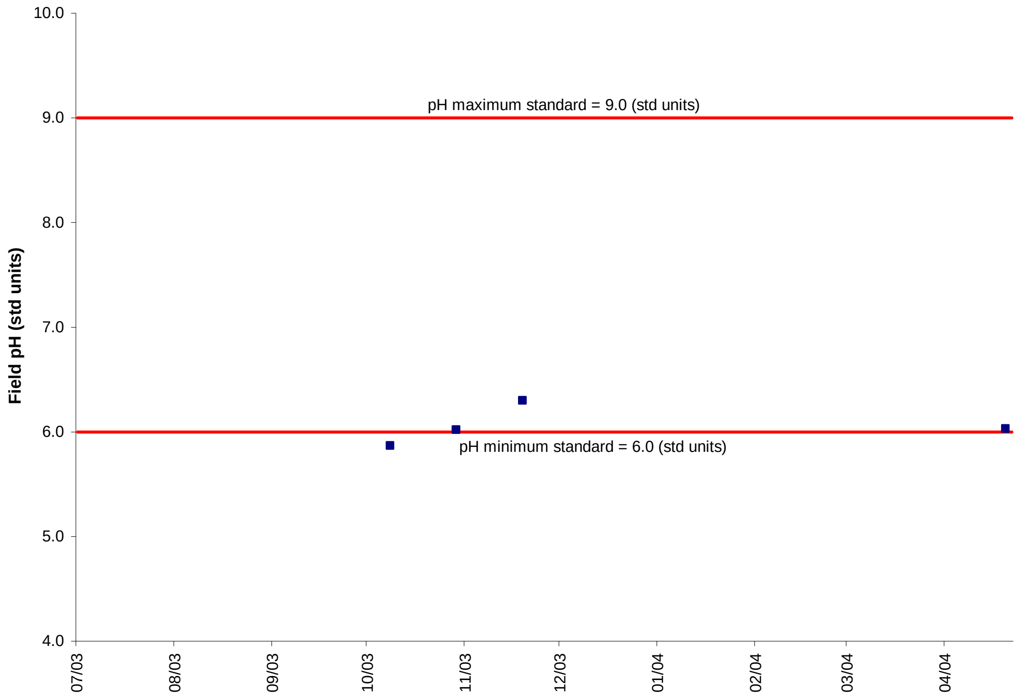

Figure B.15 Field pH at monitoring station 5ASRN003.82.

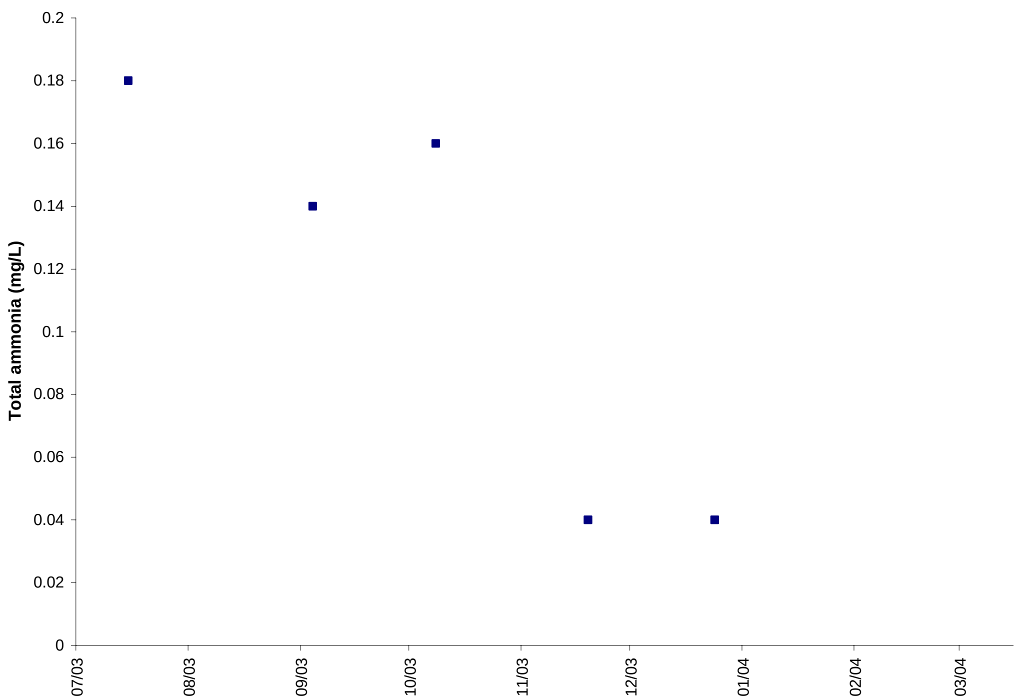

Figure B.16 Total ammonia at monitoring station 5ASRN000.65.

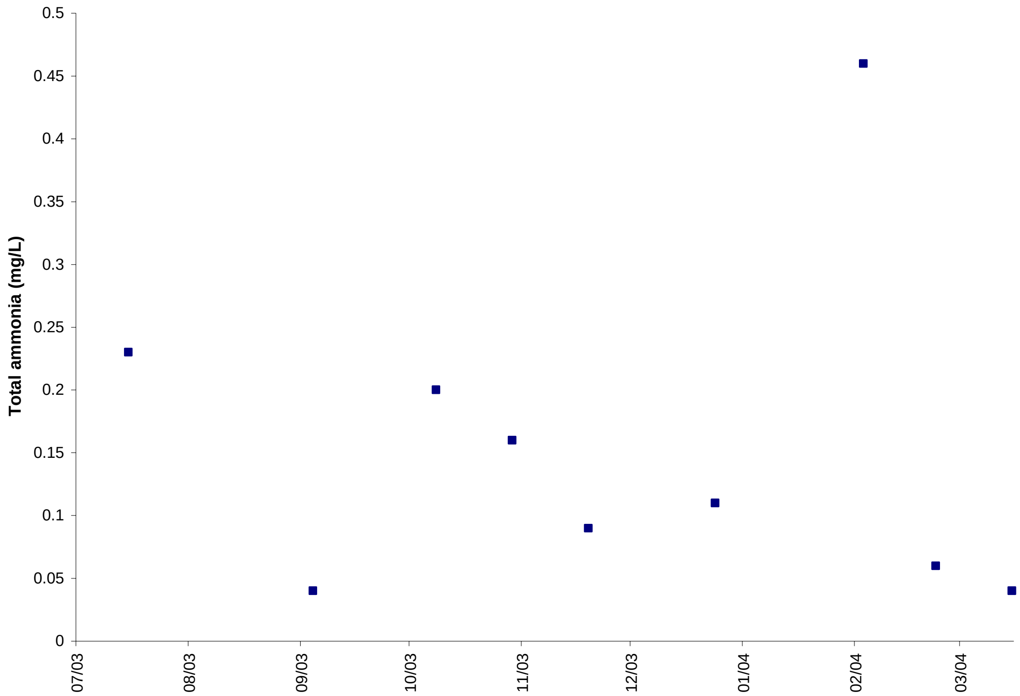

Figure B.17 Total ammonia at monitoring station 5ASRN001.24.

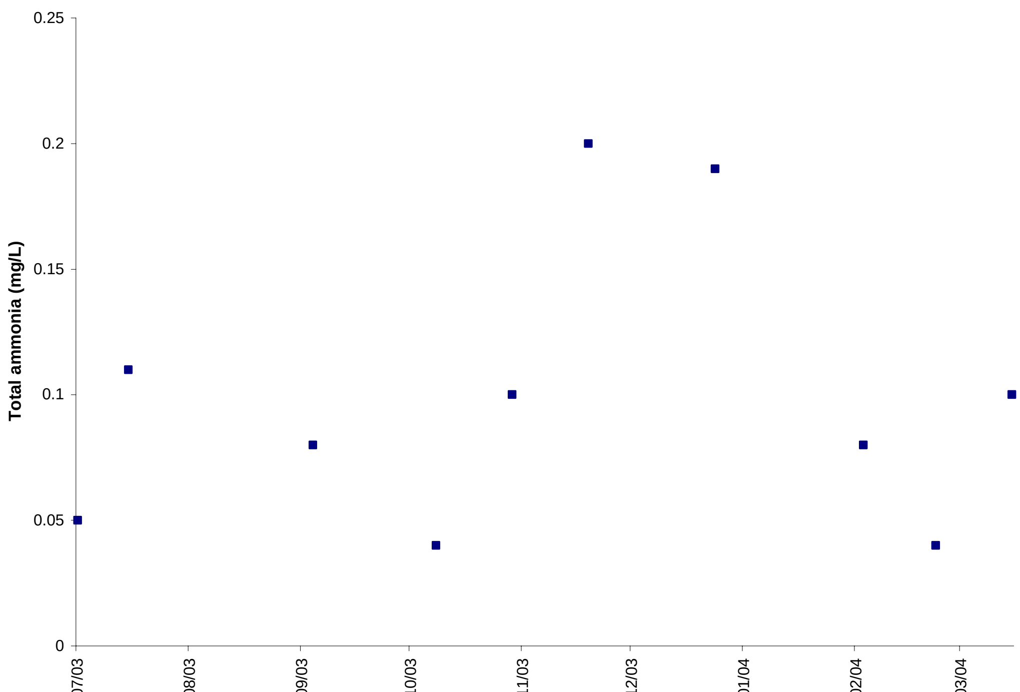

Figure B.18 Total ammonia at monitoring station 5ASRN001.99.

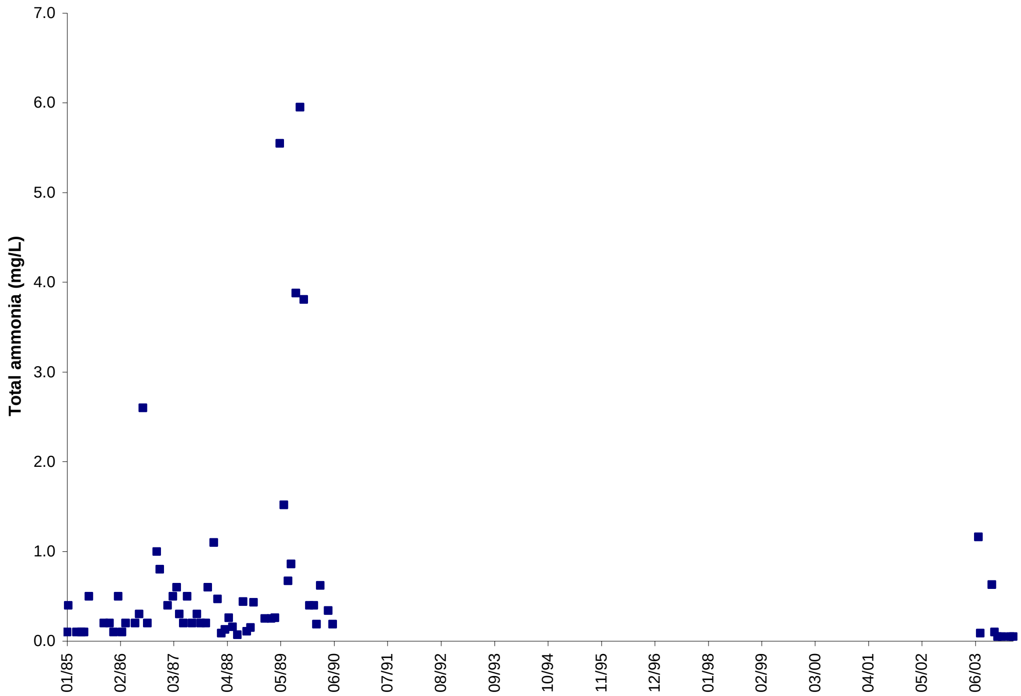

Figure B.19 Total ammonia at monitoring station 5ASRN003.69.

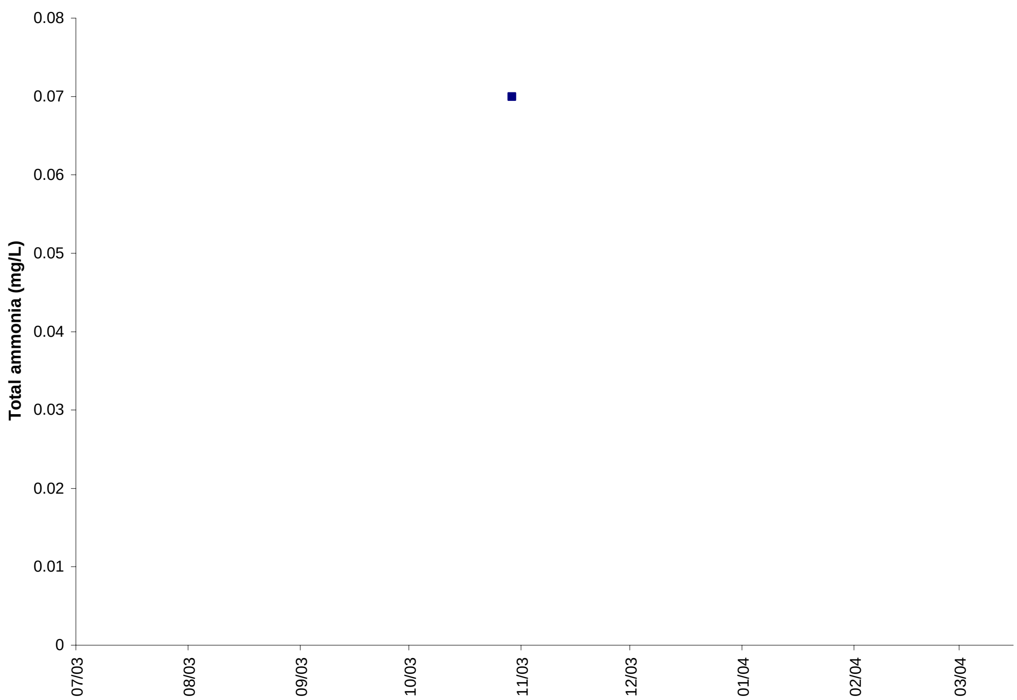

Figure B.20 Total ammonia at monitoring station 5ASRN003.82.

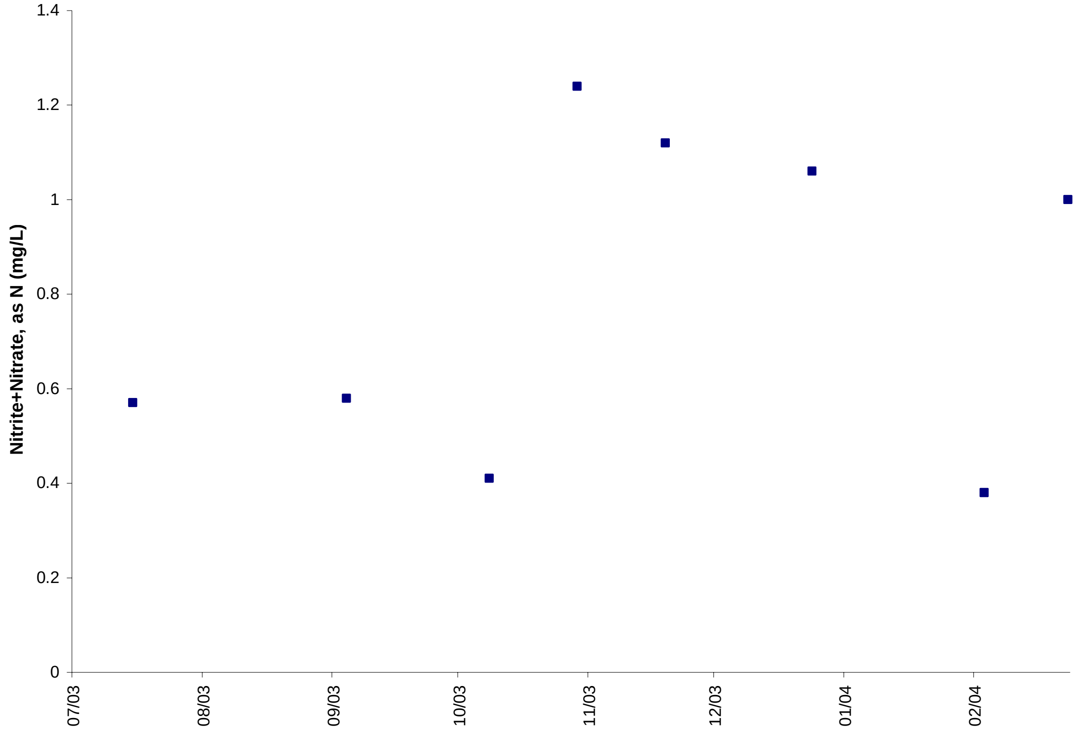

Figure B.21 Nitrite+Nitrate as N at monitoring station 5ASRN000.65.

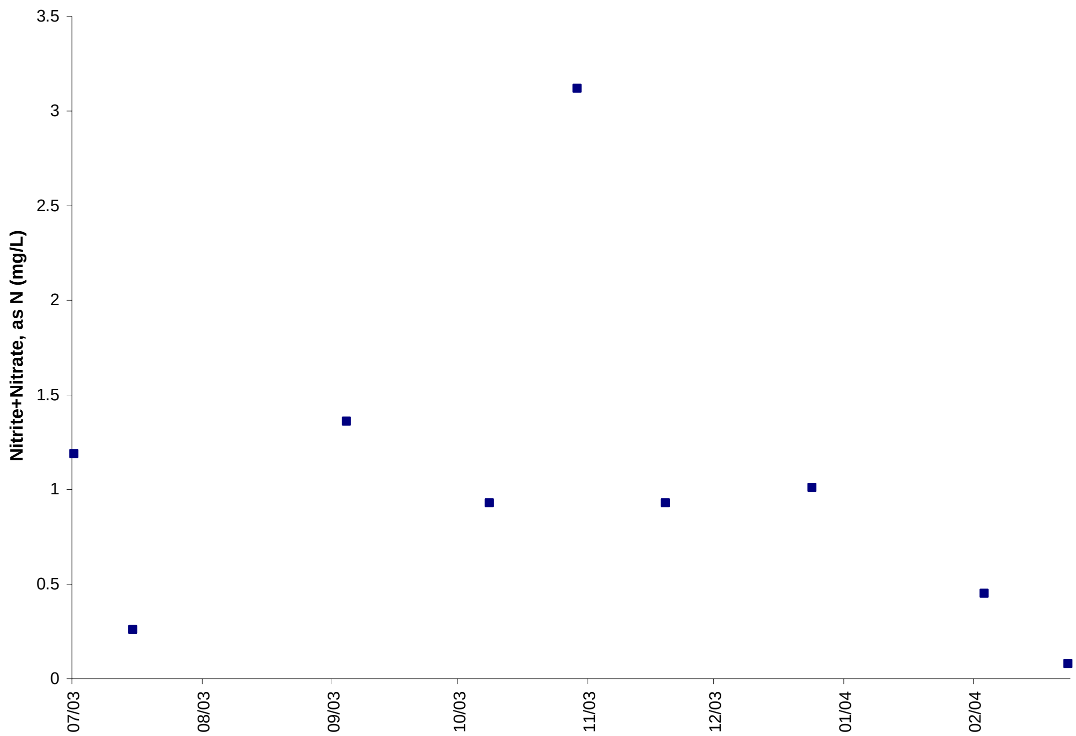

Figure B.22 Nitrite+Nitrate as N at monitoring station 5ASRN001.24.

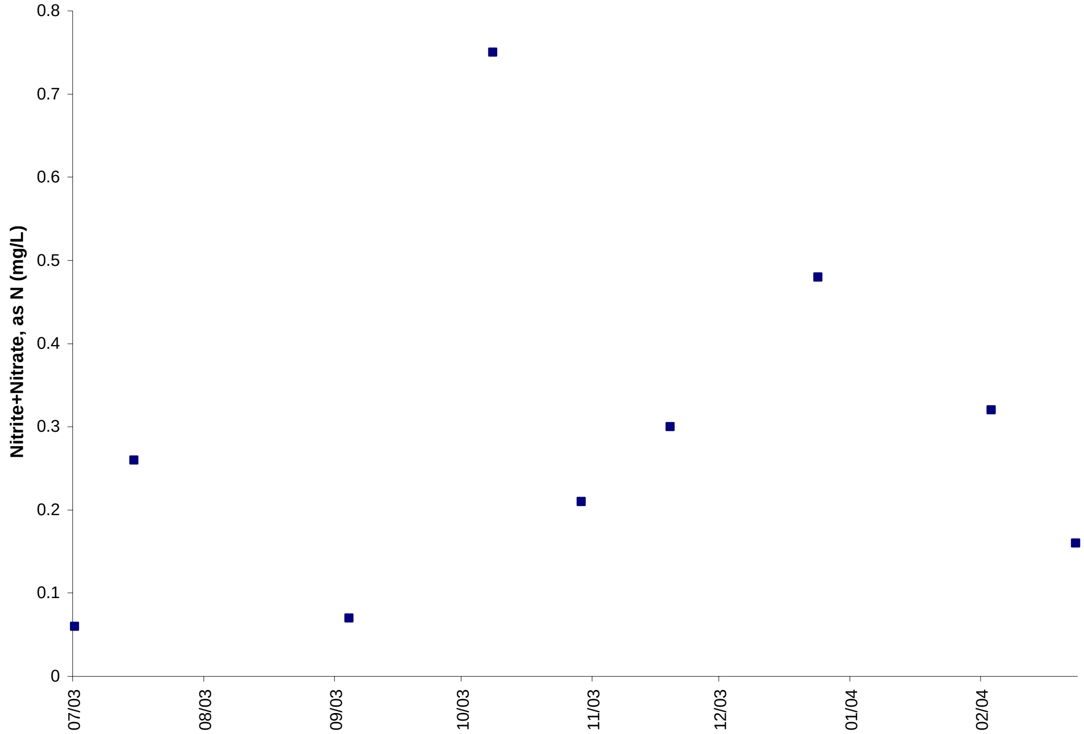

Figure B.23 Nitrite+Nitrate as N at monitoring station 5ASRN001.99.

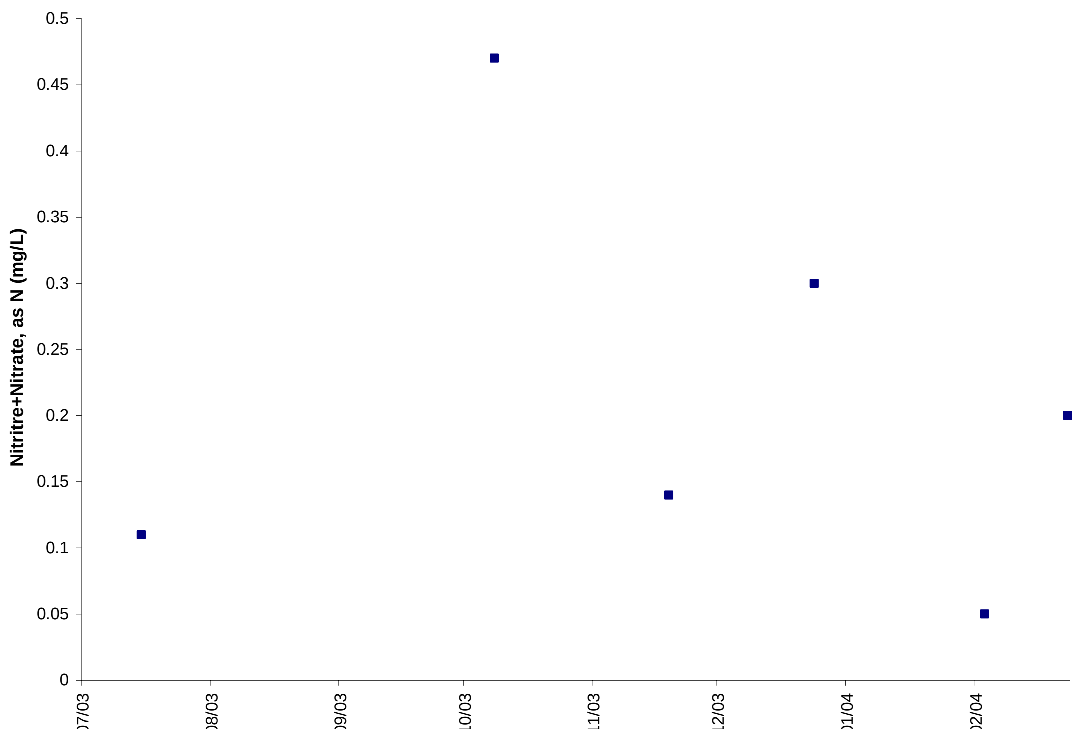

Figure B.24 Nitrite+Nitrate as N at monitoring station 5ASRN003.69.

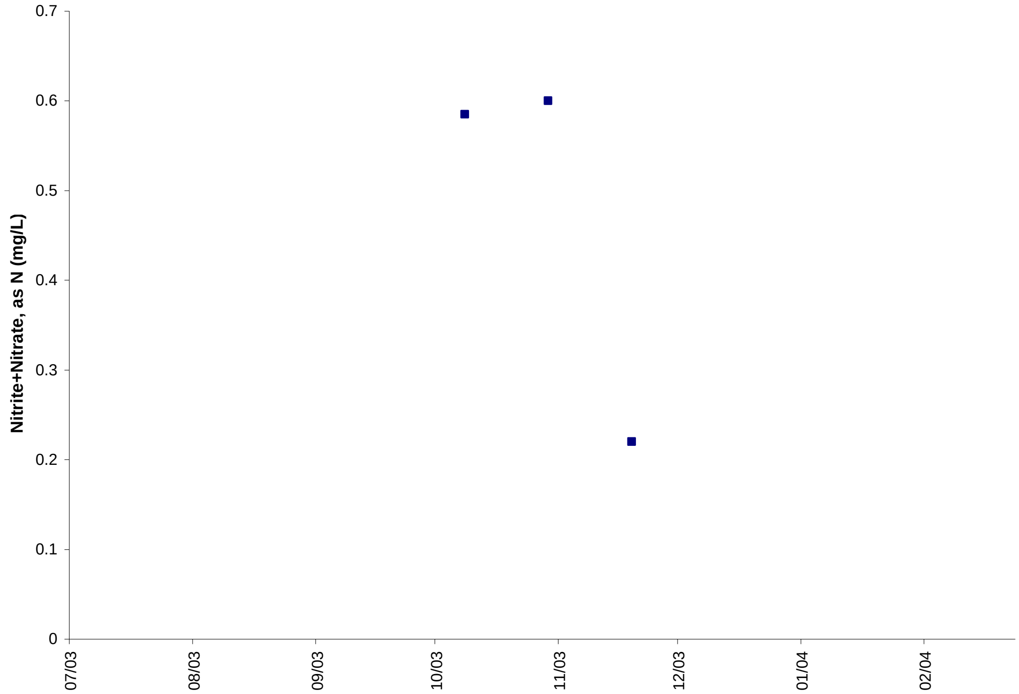

Figure B.25 Nitrite+Nitrate as N at monitoring station 5ASRN003.82.

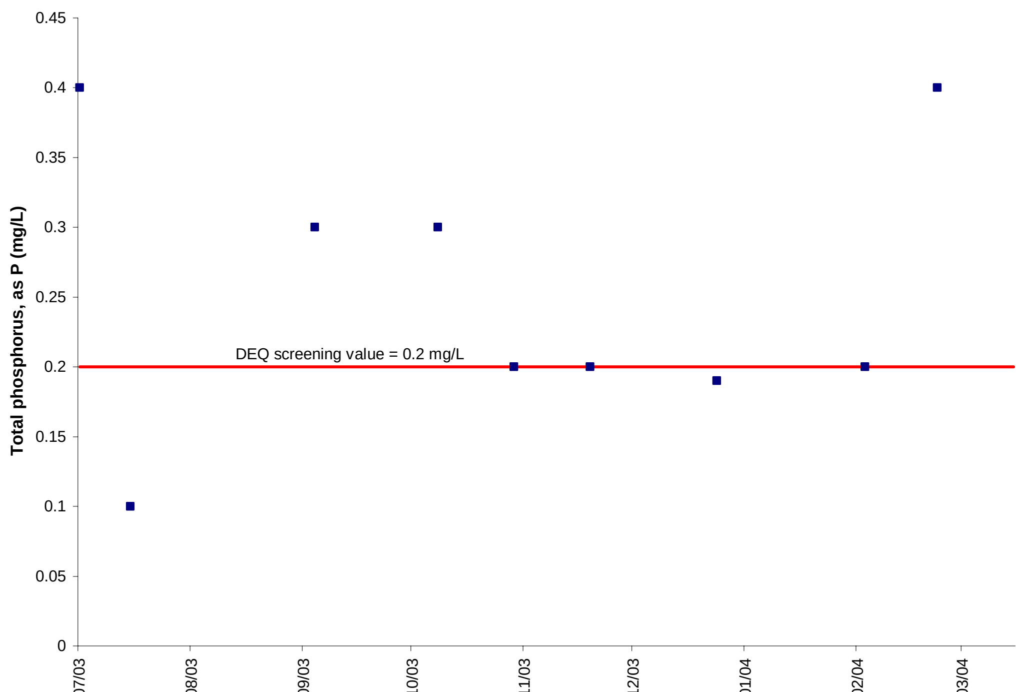

Figure B.26 Total phosphorus as P at monitoring station 5ASRN000.65.

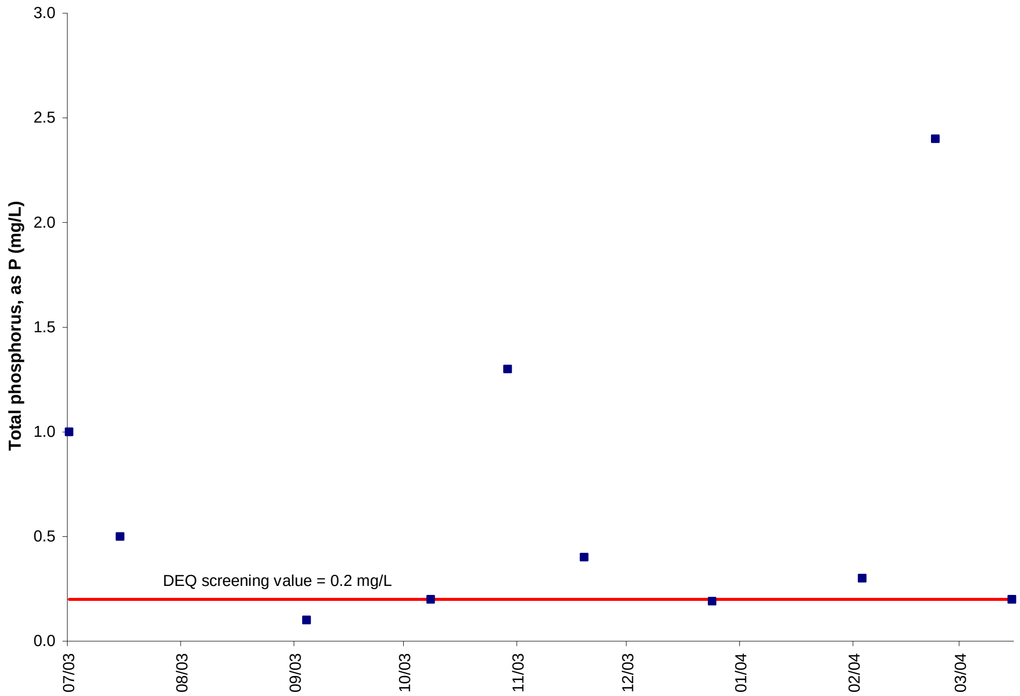

Figure B.27 Total phosphorus as P at monitoring station 5ASRN001.24.

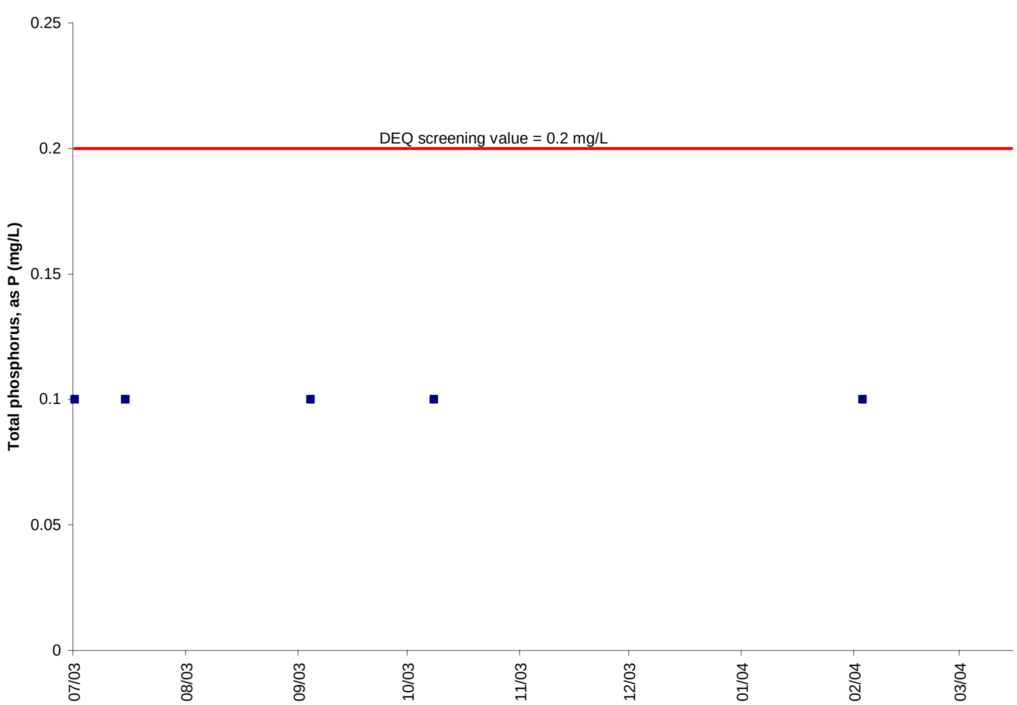

Figure B.28 Total phosphorus as P at monitoring station 5ASRN001.99.

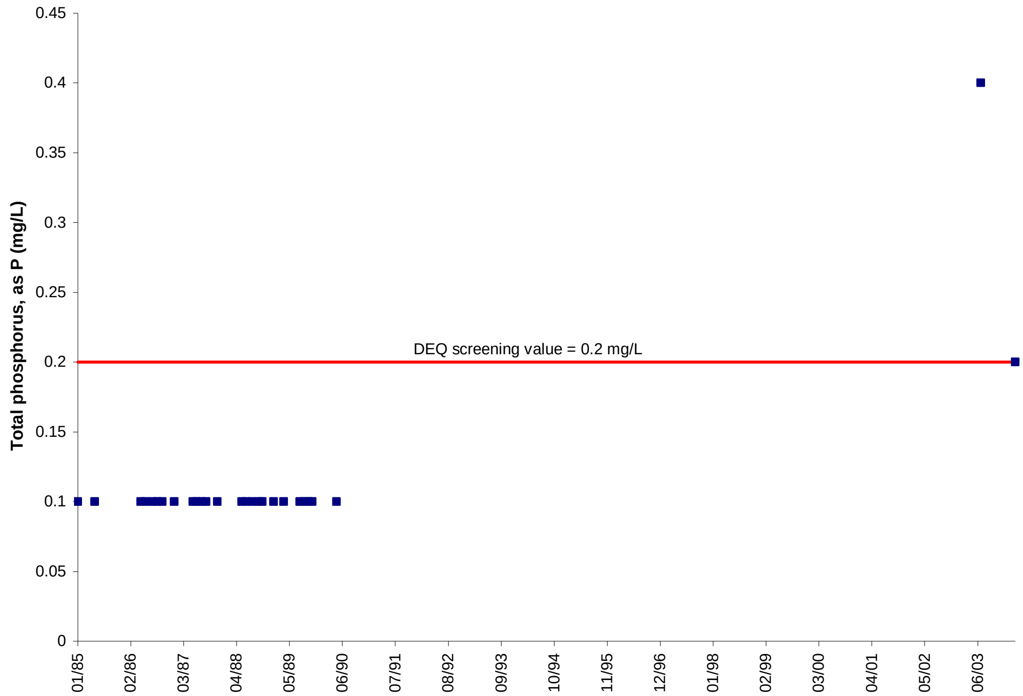

Figure B.29 Total phosphorus as P at monitoring station 5ASRN003.69.

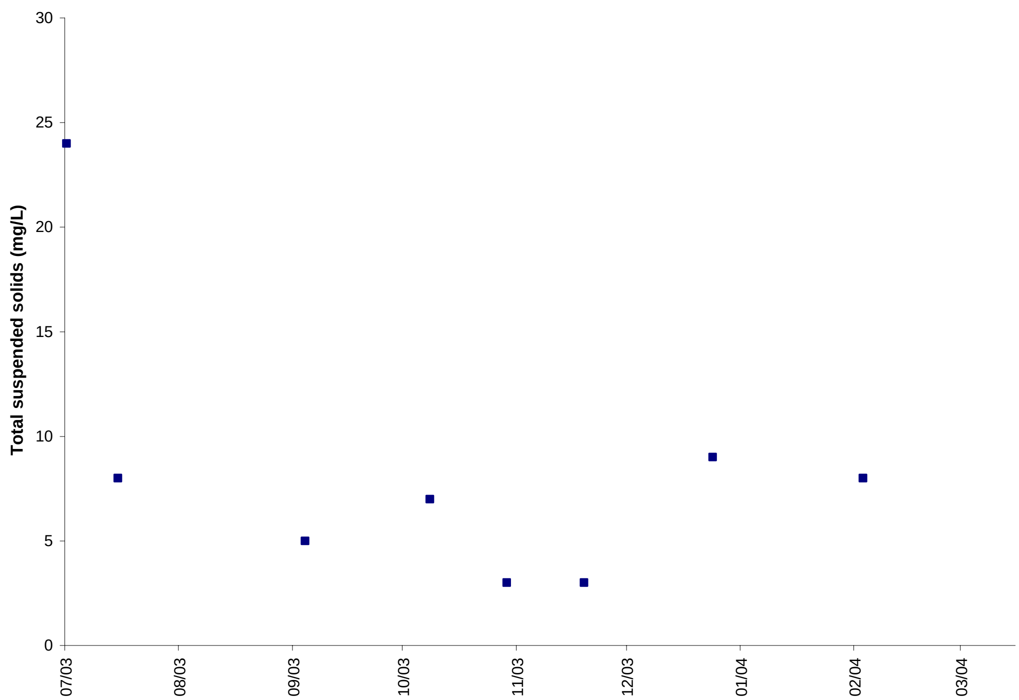

Figure B.30 Total suspended solids at monitoring station 5ASRN000.65.

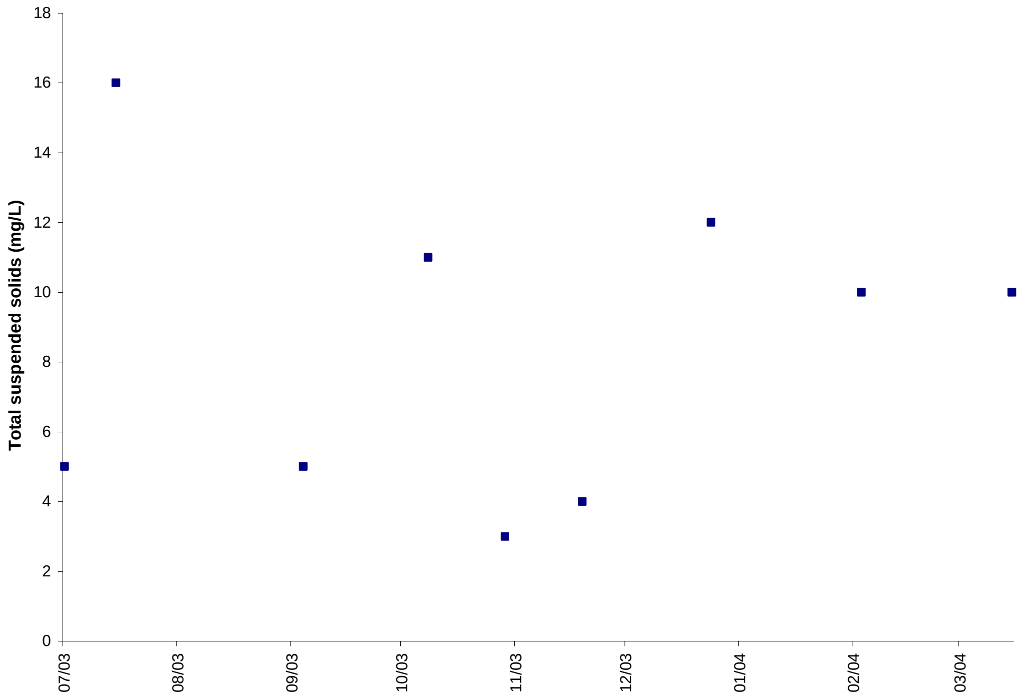

Figure B.31 Total suspended solids at monitoring station 5ASRN001.24.

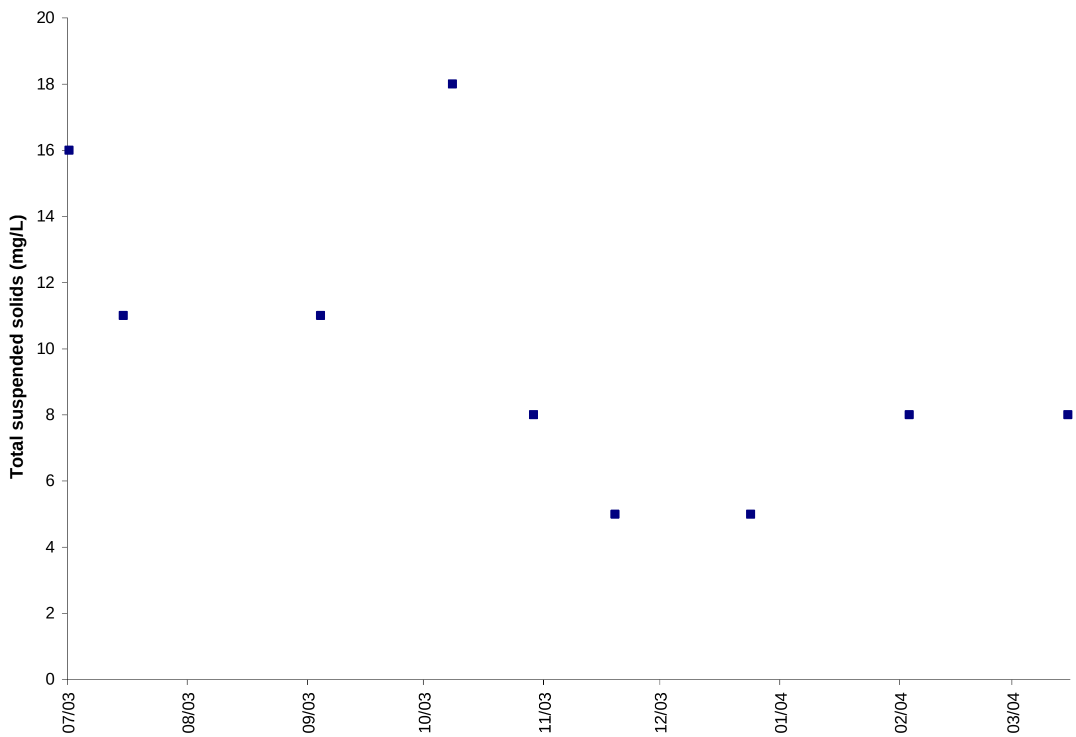

Figure B.32 Total suspended solids at monitoring station 5ASRN001.99.

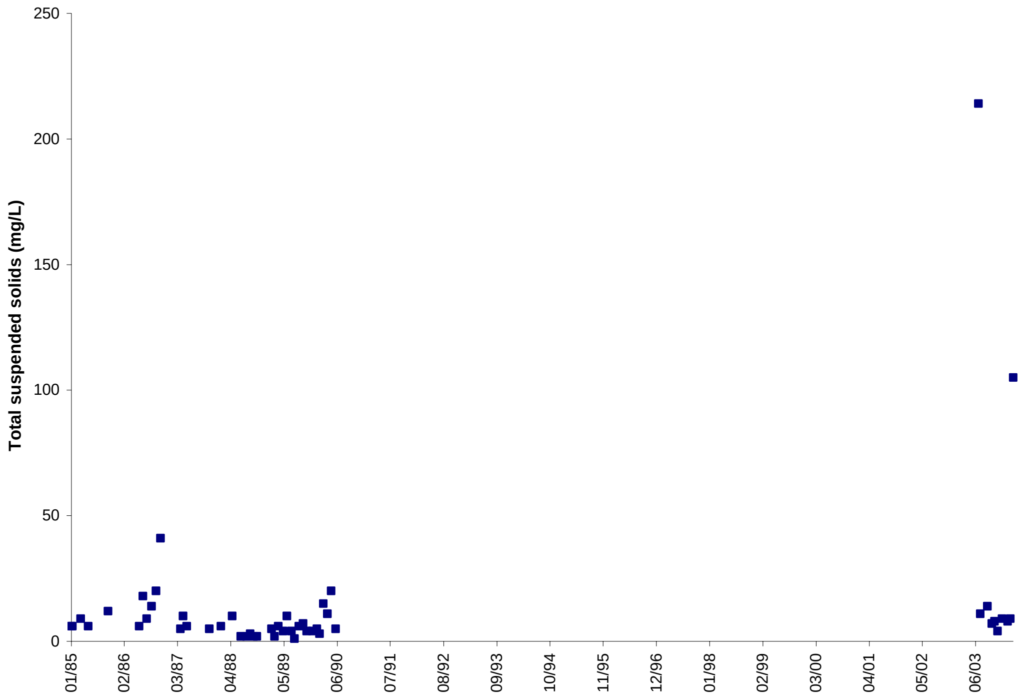

Figure B.33 Total suspended solids at monitoring station 5ASRN003.69.

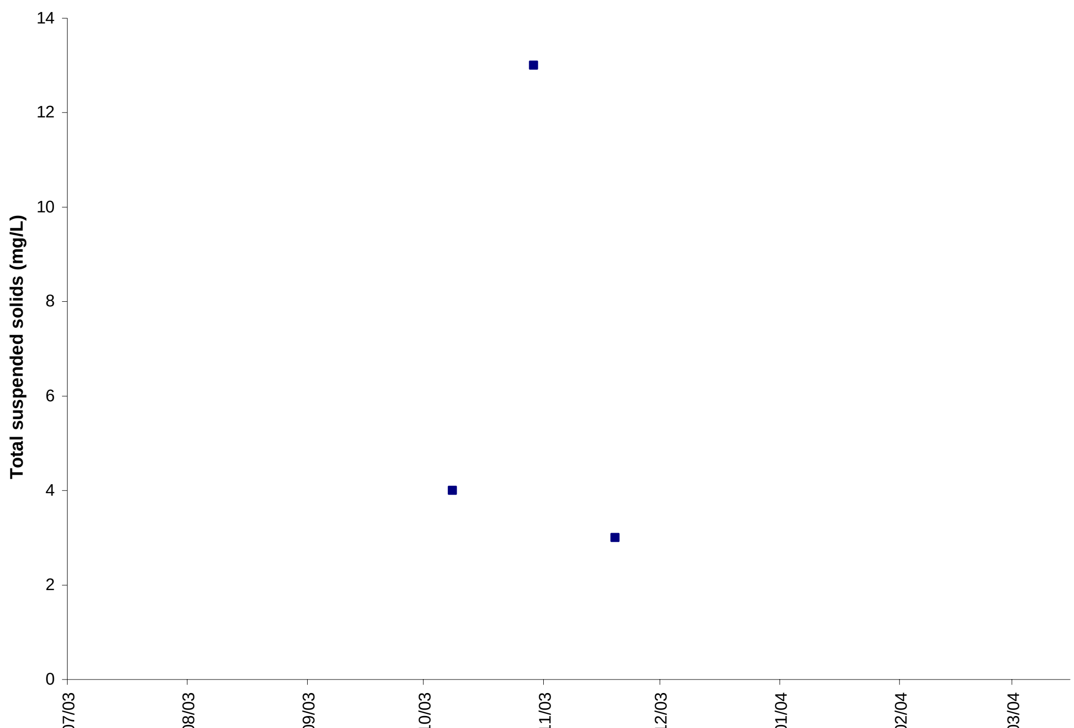

Figure B.34 Total suspended solids at monitoring station 5ASRN003.82.

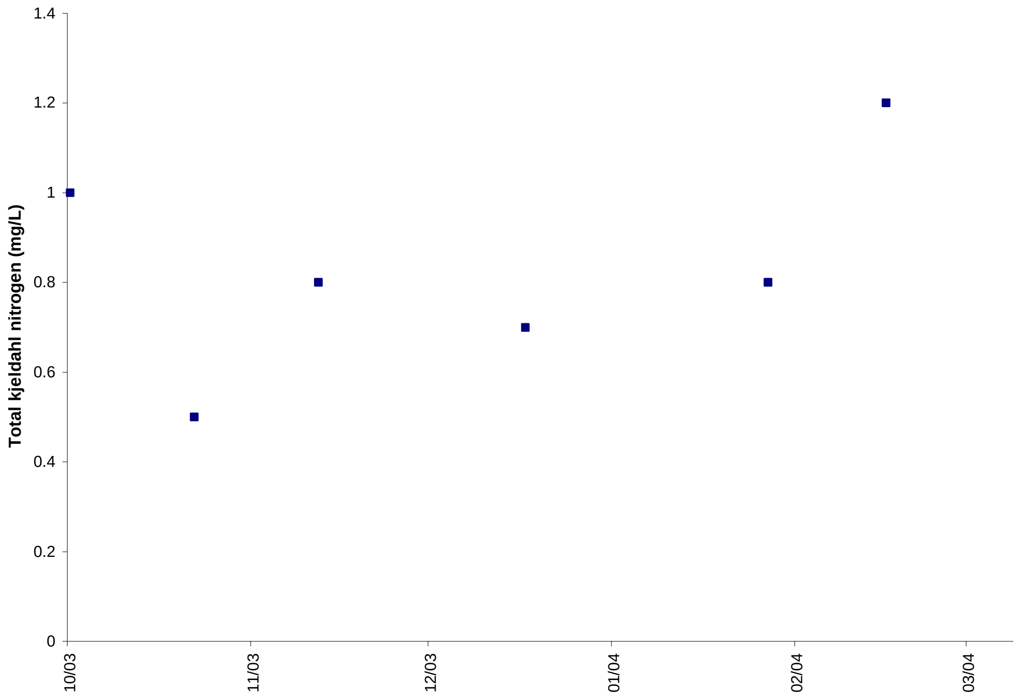

Figure B.35 Total Kjeldahl nitrogen as N at monitoring station 5ASRN000.65.

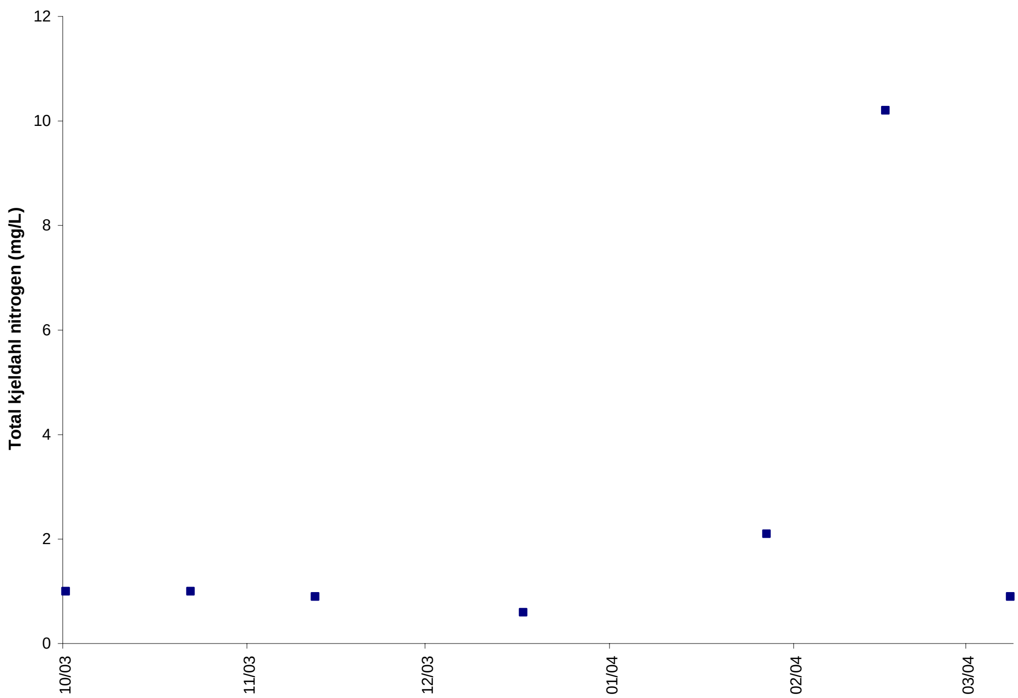

Figure B.36 Total Kjeldahl nitrogen as N at monitoring station 5ASRN001.24.

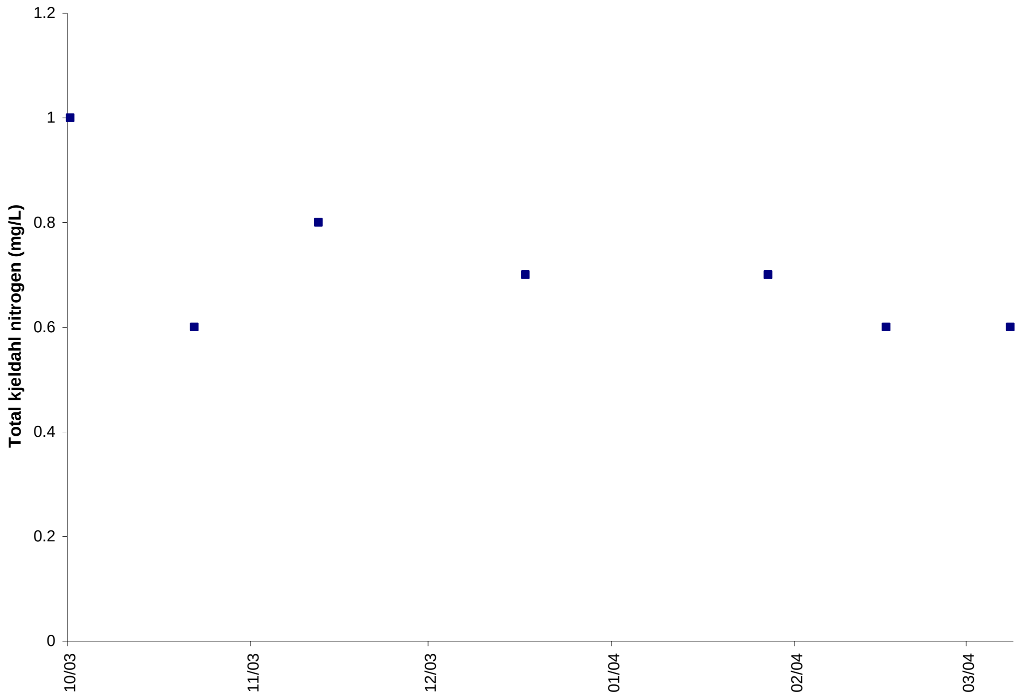

Figure B.37 Total Kjeldahl nitrogen as N at monitoring station 5ASRN001.99.

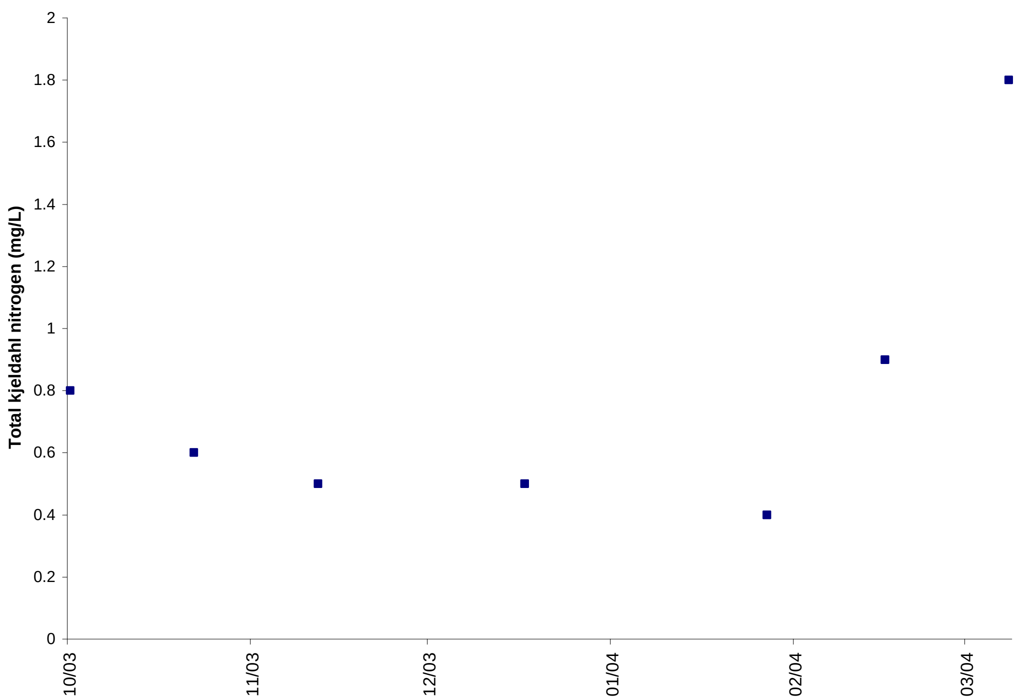

Figure B.38 Total Kjeldahl nitrogen as N at monitoring station 5ASRN003.69.

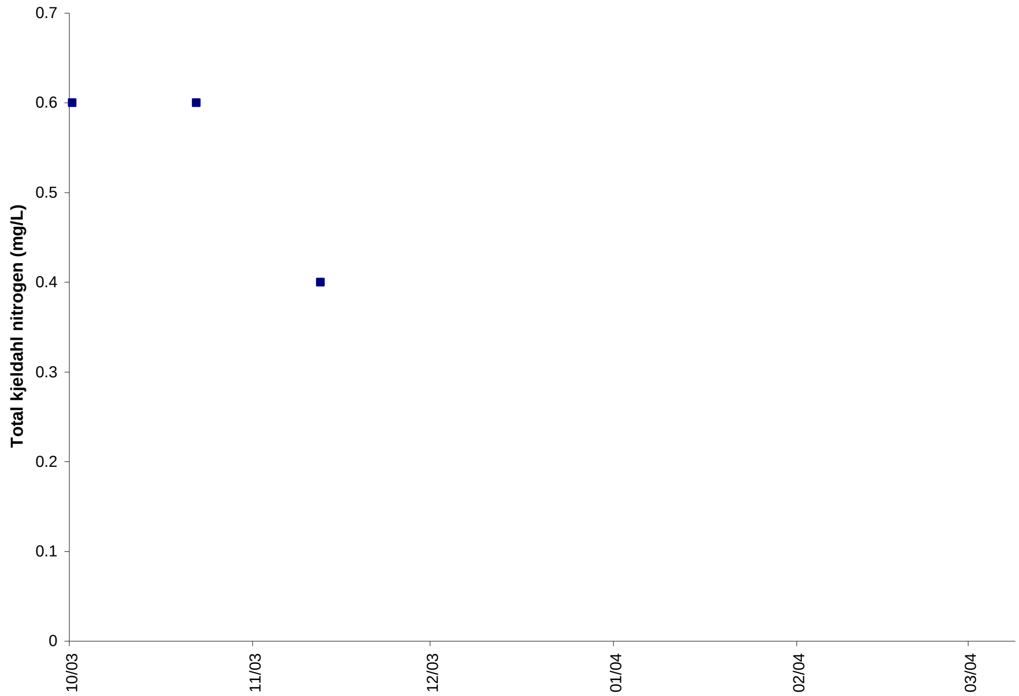

Figure B.39 Total Kjeldahl nitrogen as N at monitoring station 5ASRN003.82.

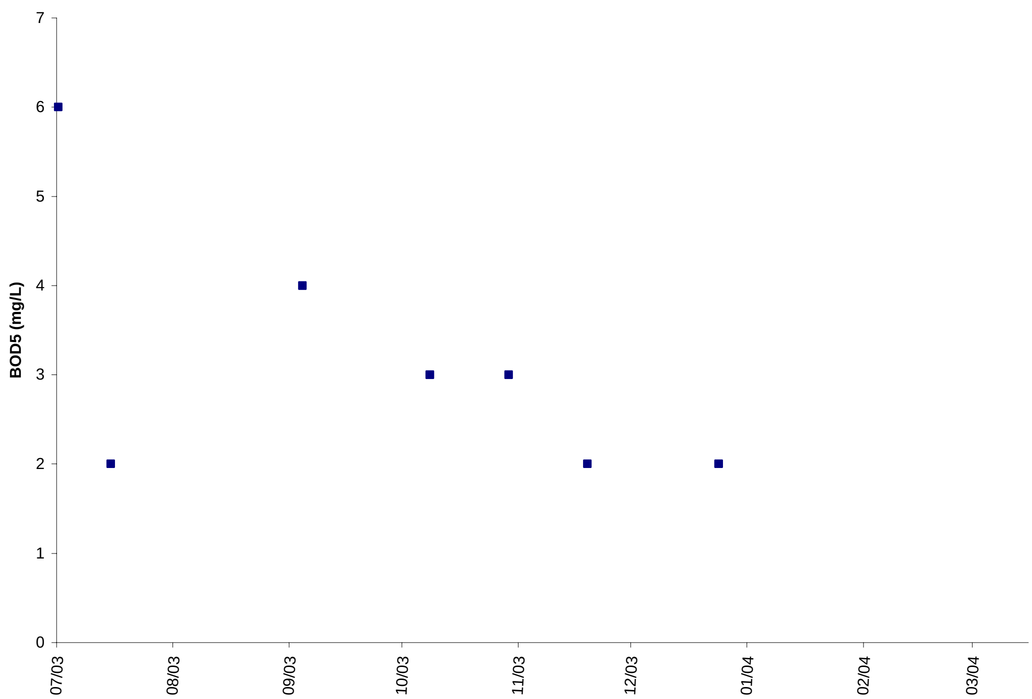

Figure B.40 Biochemical oxygen demand at monitoring station 5ASRN000.65.

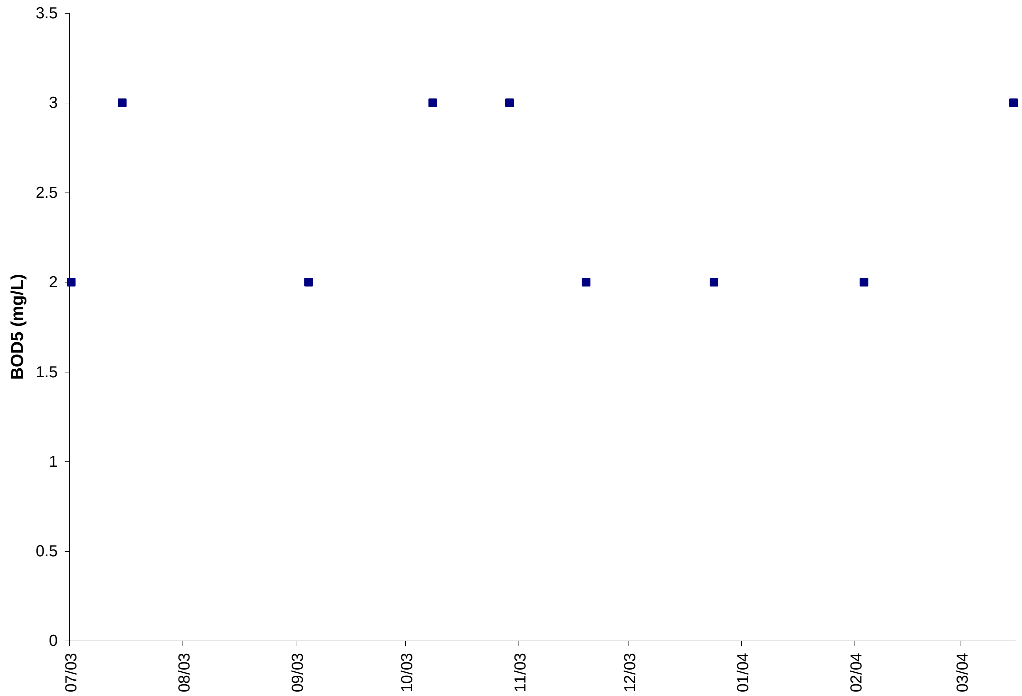

Figure B.41 Biochemical oxygen demand at monitoring station 5ASRN001.24.

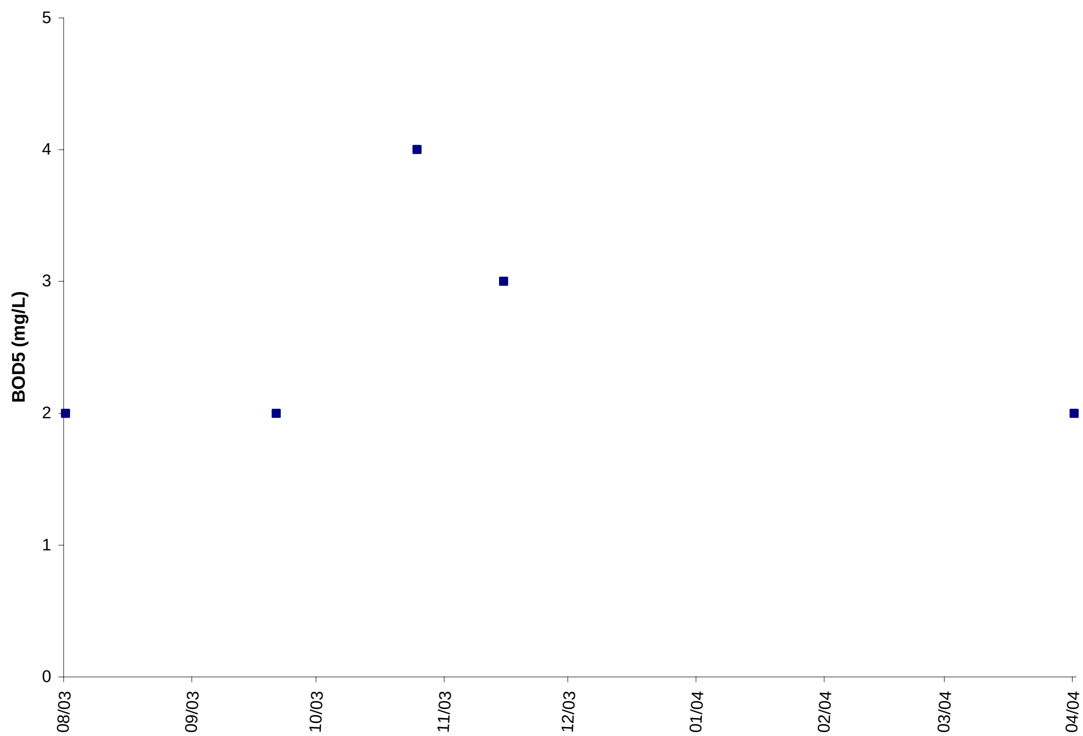

Figure B.42 Biochemical oxygen demand at monitoring station 5ASRN001.99.

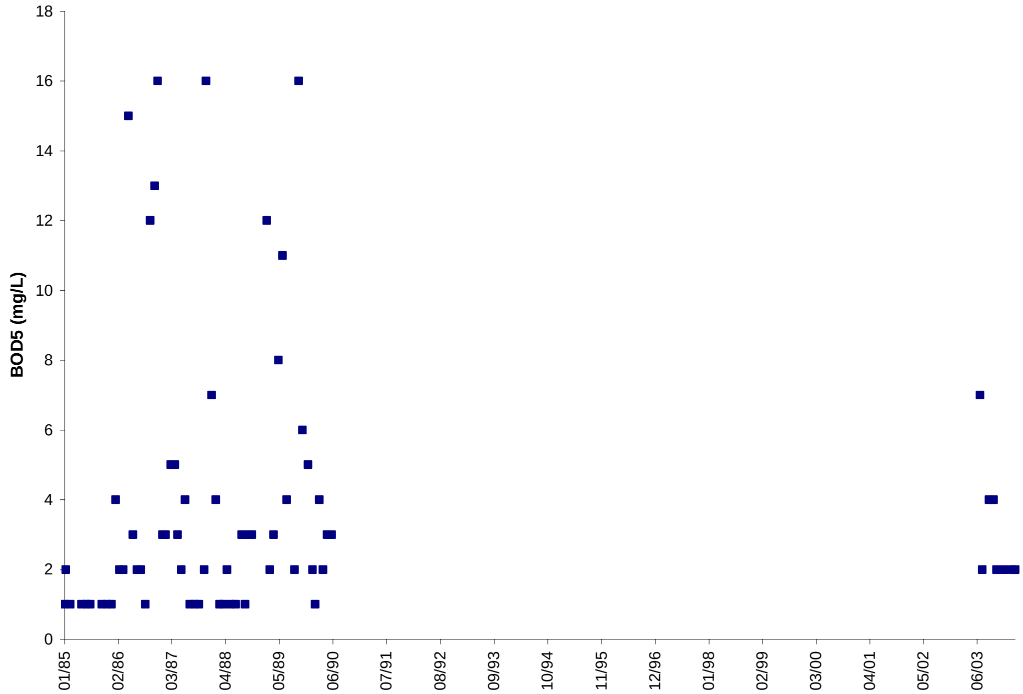

Figure B.43 Biochemical oxygen demand at monitoring station 5ASRN003.69.

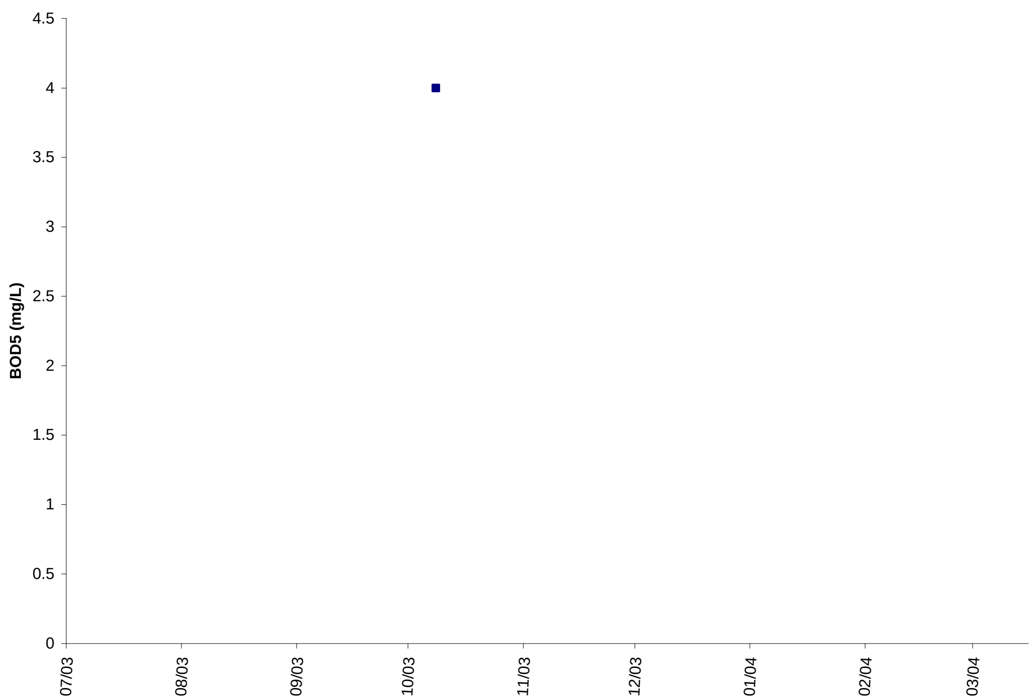

Figure B.44 Biochemical oxygen demand at monitoring station 5ASRN003.82.

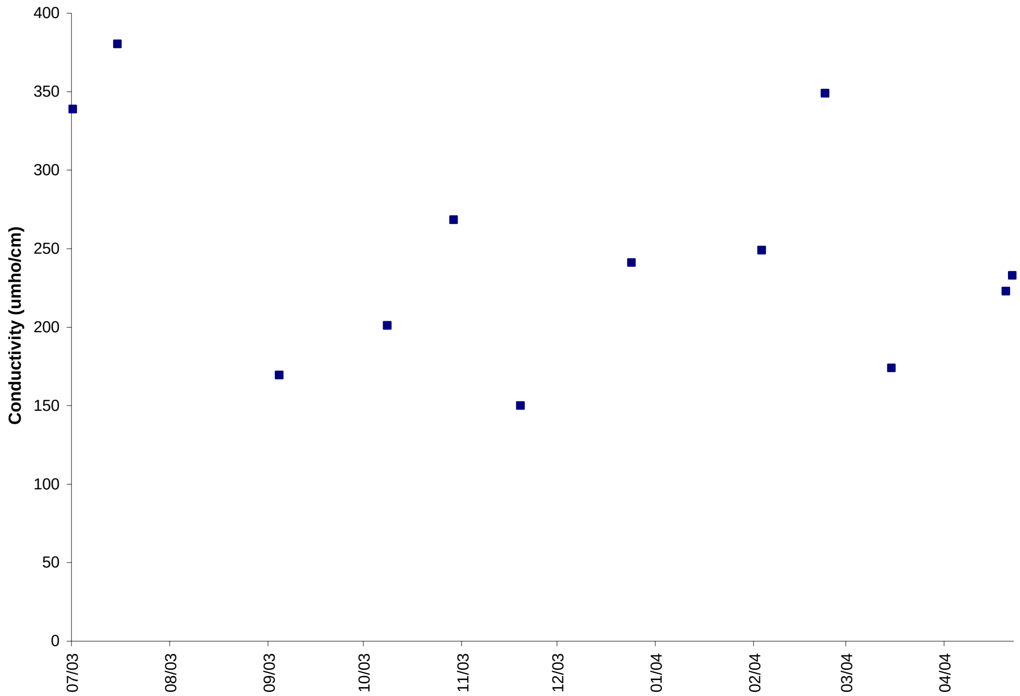

Figure B.45 Conductivity at monitoring station 5ASRN000.65.

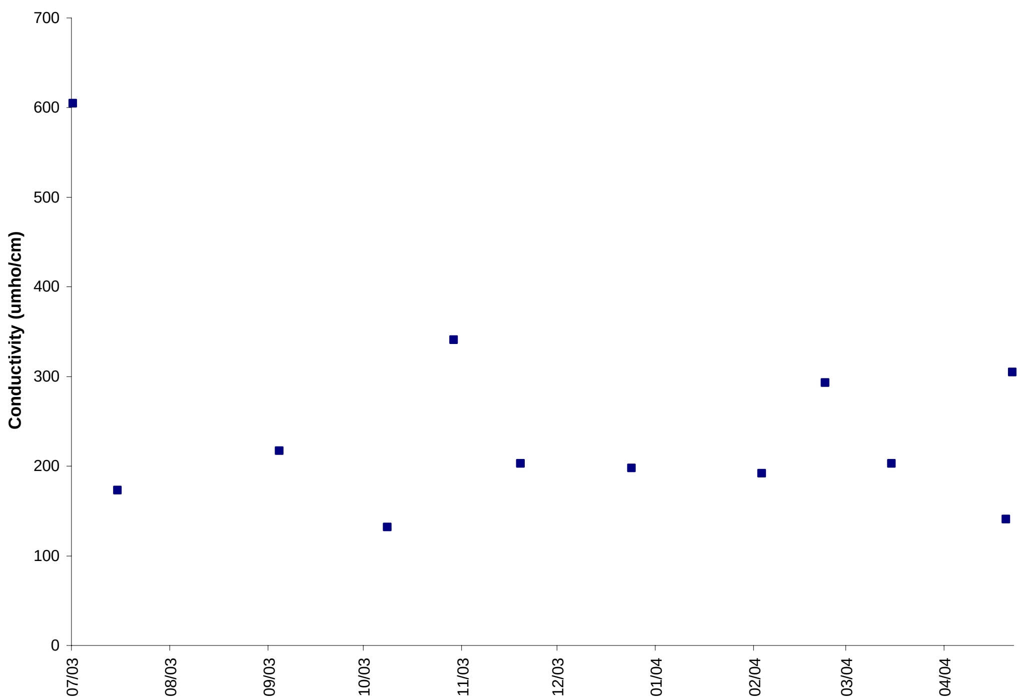

Figure B.46 Conductivity at monitoring station 5ASRN001.24.

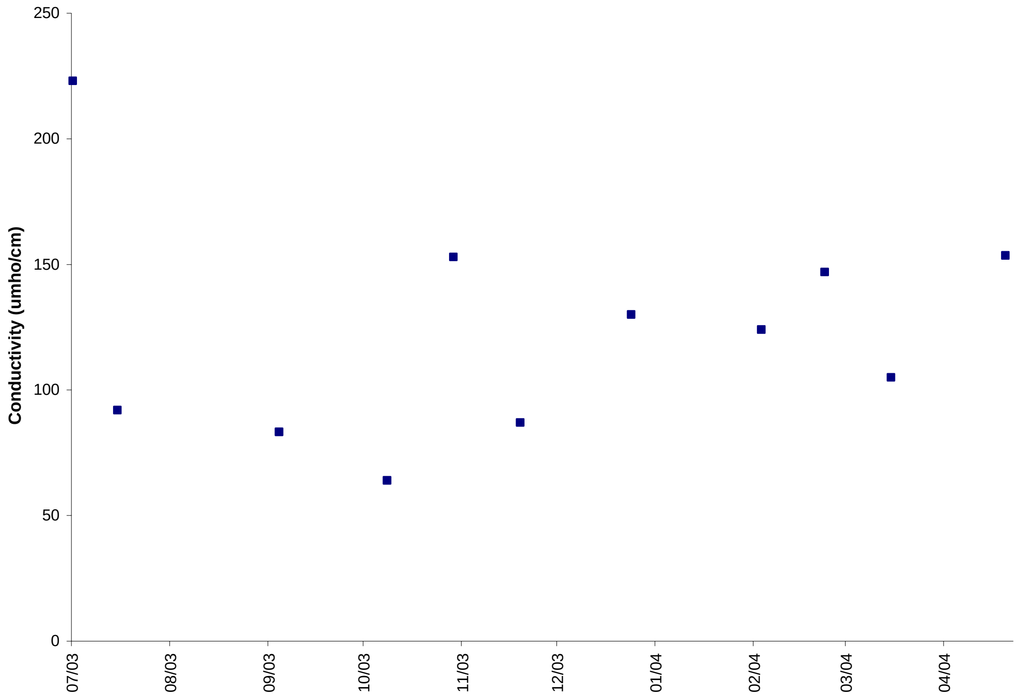

Figure B.47 Conductivity at monitoring station 5ASRN001.99.

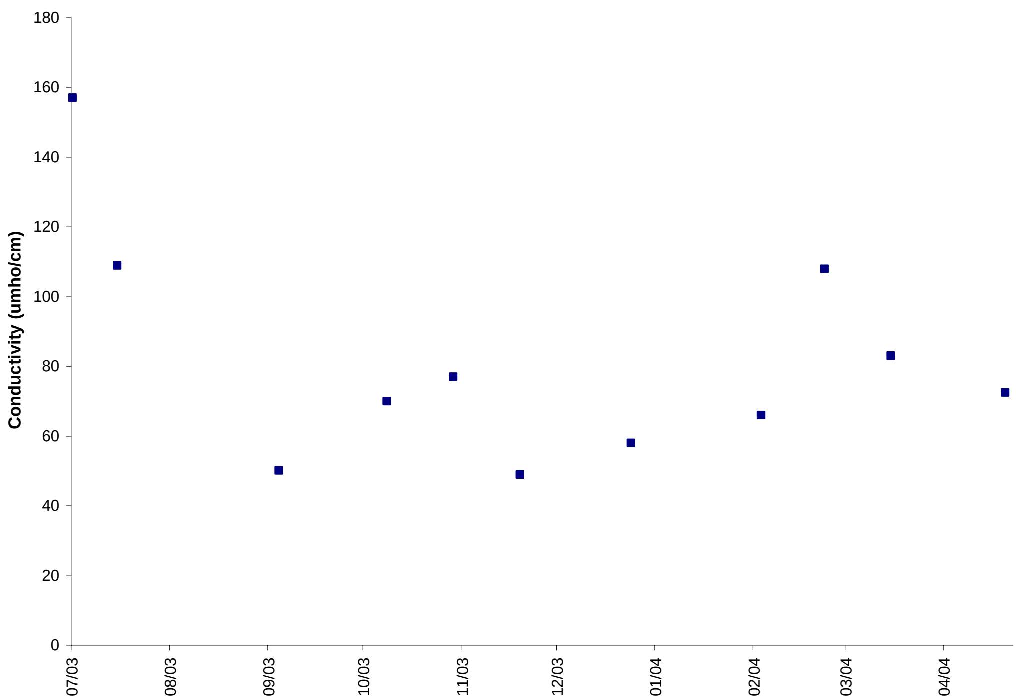

Figure B.48 Conductivity at monitoring station 5ASRN003.69.

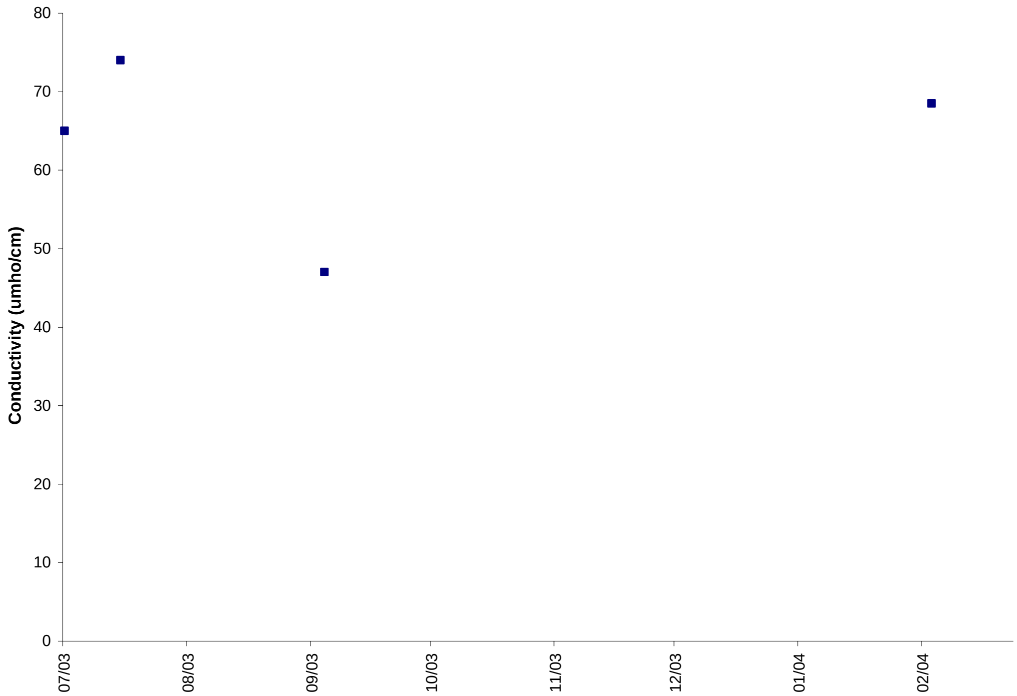

Figure B.49 Conductivity at monitoring station 5ASRN003.82.